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THE HAWAIIAN PLANTERS' RECORD

A composite picture of various factors in the production of sugar in the Hawaiian Islands.

FIRST QUARTER 1941

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

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THE HAWAIIAN PLANTERS' RECORD

Vol. XLV FIRST QUARTER 1941 No. 1

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Sugar Proceeds:

The factors contributing to, and determining the price structure of refined sugar in the retail markets of the United States are discussed. The difficulties attending the marketing of Hawaii's large crops of raw sugar are pointed out and the conclusion reached that the prevailing policy of selling as a unit, rather than in competition, must be continued if our industry is to survive.

Canton Island:

A brief description is given of this south-Pacific station on the P. A. A. route to New Zealand, together with some information as to the plant and animal life occurring there. A knowledge of Canton's insect fauna is particularly useful in connection with the Clipper plant quarantine service maintained by the H. S. P. A.

Observations on Insect Pests in Samoa Which Are Not Yet Known to Occur in Hawaii:

This illustrated paper gives an account of seventy species of injurious insects in Samoa which are not known in Hawaii; they are listed according to their food plants. Quite a number of them would prove to be serious pests if they should become established in Hawaii, and continuous vigilance should be maintained to prevent this.

Soil Fertility as Affected by Soil Nitrogen:

The use of nitrogen fertilizer in a way that will insure its maximum economic efficiency continues to be one of our most vital problems. Continually changing soil conditions, which are brought about when nitrogen fertilizers are applied and when

organic materials are added, affect the activities of the soil organisms which are active in the decomposition of this organic matter, with the result that the supplies of nitrogen available for crop growth can fluctuate sharply within small localized areas. Data are offered in this paper which contribute to a better understanding of the part that may be played by the soil organisms as they withdraw or release soil nitrogen and affect soil fertility.

Sugar Proceeds*

By R. A. Cooke

For some decades Hawaiian sugar plantations have enjoyed an enviable reputation for high efficiency—as high as that of any other group of agricultural enterprises and perhaps even higher. Early data with respect to acre-month yields or man-days performance which would be used today as the prime measures of efficiency were not kept. Still we do know that the Hawaiian crop for the year 1901 was 360,038 tons of sugar and that the number of plantation employees at that time was 39,587. Thirty-nine years ago, therefore, about 9.09 tons of sugar were produced for each employee. The corresponding ratios by decades were 12.07 tons of sugar per employee for the year 1910, 12.57 tons of sugar for 1920, and 16.47 tons of sugar for 1930. This year, according to present estimates, about 22.45 tons of raw sugar will be produced by our plantations for each worker on the pay rolls.

This, to be sure, is quite a rough measure of efficiency and, as you well know, many other factors should be included. It is, however, sufficiently accurate to establish beyond doubt a record of remarkable achievement by you and your predecessors—a record of which Hawaii and other parts of the United States are justly proud. Still, efficiency in itself is merely a means toward an end. That end is the creation of additional capital which is directly beneficial to the owners of the companies, and with no uncertainty to all others. The reverse is likewise true. If sugar is produced at a loss rather than at a profit, not only are the stockholders made unhappy but sooner or later, because of this probable depletion of the resources, all others are to some degree adversely affected.

Whether our results are profitable or otherwise depends upon two factors only—the cost of landing raw sugar at market and the price received. For annual results each of these is of equal importance. Your work has been entirely concerned with cost and almost entirely with net cost, namely, the cost of production. Unquestionably, under the law of the survival of the fittest (which law by discrimination against Hawaii has been tampered with by our Congress with its quotas and by the Sugar Division with its wage determinations), low cost at market is of vital importance to our industry. But also, without question, under the law of diminishing returns which I believe still remains intact, the room for further decreased cost is very limited. This is partially true because, as distinguished from other domestic areas, our cooperative scientific efforts have been exerted for well over half a century. As a matter of fact—with taxes, freight rates, and prices of materials all beyond our control and all on the increase, with production curtailed by quotas and minimum wages fixed by law and regulations—about the only opportunity remaining for further progress is the maintenance of present production with the use of less material and labor.

You know far more than I regarding all items governing the first factor deter-

*Presented at the Third Annual Meeting of the Hawaiian Sugar Technologists, November 25, 1940.

mining the success of our industry—the cost of landing our sugar at market. With respect to the second factor—the price received for our sugar—we who are concerned with production costs have been inclined to allow nature to pursue its own sweet course. Perhaps because you can do nothing about it, the price received has been accepted the same as the weather, except that the grumblings have been somewhat more audible and justly so. Therefore, rather than tackle you on your own home field, I am going to take you into a field which may be strange to you and tell you something about this second factor—the price we receive for our sugar. I do not mean the broad economics of sugar, but rather the general make-up of the price structure, marketing practices of the refiners, and finally the problems which confront us in endeavoring to obtain maximum net proceeds for our sugar. This field has wide expanse and much of it covered with a heavy growth of underbrush. A few high spots are set forth in official statistical tables but there are no real maps since literature on this subject seems woefully lacking. Hence if your guide, who finds himself quite out of his own bailiwick and has had to rely on oral directions given in almost a foreign language, leads you into a blind alley or wanders off the trail, you should not hold him to account.

In giving you some ideas of the price structure of sugar, I have decided to go backwards. We will start with the final price—the retail price paid by the housewife. After she obtains her sugar there is no further price change. The housewife buys her sugar in pounds and probably for this reason all sugar quotations are expressed in cents per pound. The unit used by the refineries and beet processors is usually the bag—a 100-pound bag. Occasionally they too use the pound as their unit and with their detailed cost statistics one encounters figures with decimal places long enough to have a perspective. Our unit is the short ton and since you and I are accustomed to thinking of costs and receipts at so much per ton, I will convert all data to a tonnage basis.

The official retail price of refined cane sugar is today about $104 a ton. This, however, is merely an average compiled by the government from seventy-odd cities throughout the United States. And I will add right now that implicit faith in averages has possibly caused more ruination than alcohol. A friend of mine in New York purchased on the same day two identical five-pound packages of refined sugar from two stores each within a block from his home. For one he paid 25 cents and at the other store he was charged 30 cents. The difference in these retail prices was equal to $20 a ton. Now isn't that disgusting? Here in Hawaii about $100 must be invested for the annual production of a ton of sugar and a difference of $20 a ton means the difference between a profit of 10 per cent or an equivalent serious loss. We toil and sweat to save 20 cents a ton while retail stores are throwing away $20. If, as happened a year ago, the price for our raws advances $10 a ton, there is a great hue and cry over the poor housewife, yet that poor housewife is too lazy to walk or drive in her auto two blocks to save twice that amount. Although a difference of a cent per pound or $20 a ton may be exceptional, half of that amount of difference between stores in the same community for the same grade of sugar is common. Here in Honolulu we have found a spread of $14 a ton. The reason for this wide spread is not so much because certain stores are able to purchase their supplies of sugar at a lower cost or because others are exacting exorbitant profits, but primarily because some grocers use sugar as a leader.

Below the retailers' prices there are, of course, the prices charged by the wholesalers and jobbers. So far as I know, no record of these prices officially or otherwise is kept or published. Going down the line we next have the prices of the refineries. Their daily average of public quotations for granulated sugar is $14 to $20 less than the average price of retailers. Actually the spread between retailers' and refiners' prices is much wider than that indicated by daily averages because the refiners, on account of handouts to their buyers, fall way short when it comes to their receiving the daily average of their quotations. The difference, amounting to perhaps $25 a ton, between the retailers' price and what the refiners receive seems to be shrouded in mystery. In it, of course, are included operating costs and profits of retailers, wholesalers, brokers, and other cuts, but its breakdown defies analysis.

The underdog of this price structure is of course the raw cane sugar producer. The New York market price for raws has lately been about $32 a ton less than the base price for refined. This difference, which fluctuates to quite an extent, is called the "refiners' margin." After deducting the processing tax and the loss entailed by certain sales policies, the actual refiners' margin is whittled down to say $18 a ton. Refiners have been called "nothing but Chinese laundrymen" but this is hardly fair. Only a half of the margin is needed for refining including raws lost in the process—the balance being required by the refiner for selling, distribution and overhead costs. If anything remains, which is seldom these days, the refiner gratefully records it as profit. We receive for our raw sugars $3.50 to $4.50 a ton less than the New York market price for raws, which makes us bottommost in the pile of underdogs.

But just what determines the price of sugar? I mean ignoring the effects of tariffs, quota restrictions and distribution and refining costs; why it is that the average retail price is around $100 a ton rather than twice or half that amount? We talk glibly of the law of supply and demand but just how does it operate? According to this law the price of a product in a given locality is the price at which a willing seller will sell in such locality and at which a willing buyer will buy. That sounds simple enough, but is it? The ultimate buyer is the consumer and he should not be at all unwilling if he had to pay say $120 a ton since that was the five-year average price he paid before the first World War. He purchases from the retailer, who apparently is a very willing seller as long as he makes a reasonable profit or even keeps to a slight loss. But the retailer is also a buyer since he must purchase his sugar from wholesalers or jobbers who in turn are buyers as well as sellers since they must obtain their supplies either from the cane sugar refineries, the beet companies or from plantations which refine their own sugar. But cane sugar refineries themselves are buyers as well as sellers since their willingness to sell at a certain price depends upon the price which they must pay for raws. And, finally, we have the poor producers of raw cane sugar, who are not at all happy over selling their product at what has been termed tragically low prices, but since they can do little or nothing about it, I suppose, with our fingers crossed, we will have to class them as willing.

Someone along this house that Jack built is responsible for the price of sugar, but who? Is it a question of whether the hen laid the first egg or the egg hatched the first chick? The answer probably is that the housewife, retailer, wholesaler, refiner, and raw producer all exert some influence, but in each case the character

and extent of it is constantly subject to the whims of that elusive autocrat—general conditions. For example, in the early years of the first World War, when the sugar supplies from central Europe were cut off, there was a definite shortage of raw sugar and the sellers of raws were probably the prime factor in determining the price of sugar. Last year, on the declaration of war, consumers became panicky and demanded more sugar for prompt delivery than was immediately available. Because of their demand retailers increased their prices to eight and ten cents a pound and even higher. I heard of one willing buyer who paid nineteen cents a pound—$380 a ton! All producers were not only willing but anxious sellers at only a fraction of these prices but their sugars were not available in the shape of refined at the right places at the right time. Wholesale prices of refined and also raw prices advanced because of the demand of consumers. During 1918 and 1919, because of the shortage of sugar supplies, the government fixed the prices for both raws and refined, but took no action with respect to retail prices. Under those conditions the distributors—retailers, wholesalers, and jobbers—were the principal factors governing retail prices. Usually the difference between retail and refiners' prices is around $20 a ton, but during those two years this difference averaged $80 a ton. The distributors took advantage of the situation and cashed in.

But, except under unusual circumstances, the standard cane sugar refineries exert by far the most dominant influence on the whole chain of sugar prices. Being the first in the field, handling as they do about two thirds of the sugar sold and being practically the sole purchasers of all raw sugars, it is natural that they should be the bellwethers of the sugar market. But even their influence is decidedly restricted by the sellers of raws and many other forces beyond their control. As a result of the refiners' influence on price levels, there is a more or less fixed relationship between prices of all sugars throughout the United States. In other words, the principal standard to which other prices are related is the cane sugar refiners' wholesale price for granulated refined sugar. This is the big umbrella and while others than the refiners do lift or lower and at times tilt this umbrella, its shape is kept fairly constant.

The surface of this price umbrella is not, speaking geometrically, a plane surface since it not only has length and breadth but also thickness. I have already pointed out that this thickness—the difference between the retailers' price on the top and the raw price on the bottom—amounts to about $50 a ton. The refiners' granulated price is located about in the middle. Above the refiners' price and directly related to it are the wholesalers' and jobbers' prices and also all the refiners' prices for specialties—cubes, powdered sugar, etc. Below this price and almost as directly related to it are the beet sugar prices and prices of sugars refined by plantations. The lowest stratum consists of the raw prices. These can fluctuate to quite an extent without disturbing the other various price strata, but if there is a change in the refiners' granulated price, all other prices, except raws, move almost in unison.

Besides not being a plane surface, the refiners' price umbrella is not by any manner of means a flat surface. This is because the price structure is built upon the basing point system. Let me explain what I mean. Each cane sugar refiner adds to his price, so far as he is able to do so, the cost of transporting his sugar from his refinery to the locality in which his sugar is to be sold. The price basis, therefore, in each city of the United States is the lowest price at which sugar can

theoretically be delivered in that city by a cane sugar refinery. For instance, the lowest freight rate from any cane sugar refinery to Chicago is at present $6.40 a ton. The price basis for cane sugar in Chicago is therefore $6.40 over the wholesale price of refined. If because of its locality it costs a refinery $10.40 to transport sugar to Chicago, that refinery must absorb an extra cost of $4.00 a ton on sugar marketed there. This is called "freight absorption." On the other hand, if it costs a beet processor only $2.40 a ton to transport his sugar to Chicago, he has a price advantage of $4.00 a ton. This is called a "freight pickup." Beet processors, offshore refiners and occasionally small mainland refineries are able to gain by freight pickups. The standard cane refineries cannot do so directly since they are the ones who were forced to establish and who must now maintain the price structure.

There are about half a dozen small refining plants in New York and Louisiana which produce but a few grades and packages and which generally sell below the established price basis. The so-called "standard" cane sugar refineries are eighteen in number, each with a wide distribution, overlapping and coming into competition one with the other. Their prices must be kept in line. If the prices of any one of them are over the general level, that refinery, because of competition, will be unable to sell, while if they quote prices below those of their competitors, the others must meet the reduction or they in turn will lose business. All eighteen are located where their supplies of raw sugars can be most economically obtained and since most of the raw sugar is shipped from Hawaii, Puerto Rico, the Philippines, and Cuba, they are built on ocean harbors where satisfactory dockage facilities are available. Each of these refineries is a basing point. Often because of competition of whites from Cuba and Puerto Rico, other ports along the Atlantic seaboard where there are no refineries are established as basing points.

Therefore, the shape of the sugar price umbrella resembles quite closely the general contour of continental United States. The lowest points are along the coasts, with slight humps between ports, a dip in the Gulf because of cheaper raw sugar freights from Cuba and Puerto Rico, a slight rise in San Francisco and again humps in Los Angeles and the ports of the Northwest. As we leave the coast and go inland the price level rises—somewhat more abruptly in the West than in the East and rather gradually up the valley of the Mississippi because of the relatively lower costs of river transportation.

Because of the importance of the sugar cane refineries to sugar prices, and also since our plantations own and operate the California and Hawaiian Sugar Refining Corporation, known as C. and H., I am going to discuss some of their marketing practices and problems. Before doing so, however, I am going to say a few more words on the discount accepted on beet sugars and offshore refined sugar. These sugars always sell from two to four dollars a ton and sometimes much more below the price obtained by the cane sugar refineries even though there may be no difference whatsoever in quality. Why is this? It certainly is not because of any sympathy for the consumer. The cane refineries have the chance of taking reductions out of the hide of the raw producers but with beets and offshores, discounts come out of their own pockets. The reason is partly psychological and partly practical. Formerly, beet sugar, and this still applies more or less to offshores, was inferior in quality and for this reason could not command prices equal to refined cane.

Although no one but an expert can now detect any difference between refined cane sugar and good beet sugar, the reputation of being inferior persists. The ballasting of the Malolo may be perfected, its name may be changed, but the Matsonia is still erroneously considered by many a roller. The practical reason for the discount on beets, called the beet differential, is that wholesalers and jobbers as a rule desire their sugars in various grades and packages. Beets cannot supply many of these. C. and H., for example, regularly quotes 34 different grades of refined sugar packed in 135 different forms and sizes of containers. Plantations and small refineries are handicapped not only by being unable to supply assortments but also because at times they cannot provide the quantity desired.

Just as the cane refineries' basing point system and beet and offshore whites differentials have developed and are now accepted as "customs of the trade," other marketing practices have evolved and have been in use so long that they are now taken for granted. Consider, for example, the 2 per cent cash discount allowed by both beet and cane refineries for payment within ten days after delivery. Two per cent for ten days is equivalent to an annual interest rate of 73 per cent. If this cash discount could be reduced to one per cent, which should be ample inducement for prompt payment with money as cheap as it is, the theoretical saving would be almost $1.00 a ton.

But of much greater consequence is the practice of giving customers a day's notice of any advance in the price and permitting them to book orders at the old price. Mind you, they do not buy but merely contract to buy. And the contract is entirely one-sided. If the buyer wants the sugar he demands delivery and makes payment at the old price less 2 per cent within ten days. But if the buyer finds that he cannot resell at a profit, the seller is left holding the bag or bags. If the price declines, his contract is cancelled and he can wait until another notice of advance and book again. Bookings used to be limited to customers' requirements from 7 to 30 days but recently contracts extending for many months have been given. The result of this practice of advance price announcements is that about four-fifths of the sugar sales of the refiners occur between the time of announcements and the time they become effective. During a year there may be less than a dozen of such announcements. It therefore follows that except for a few day-by-day sales, the refiner never receives any peak quotation.

The practice of giving an advance notice of an increase in price seems to be an overgenerous concession but cannot be avoided. Bear in mind that sugar is a uniform product and that every part of the United States is or can be supplied by many large sellers, both beet and cane refiners. Each of these has, after many years of effort, built up its coterie of customers and a customer lost is not easily regained. An advance in price must be made by individual initiative since any agreement on the part of the sellers would be illegal. If one seller, because of his judgment of marketing conditions, advanced his price without notice, he would hand over his customers to his competitors. Unless bookings were permitted on a notice of advance, there would not be much chance for increased prices. But allowing customers to book their requirements for many weeks and even months, is nothing more nor less than "cutthroat" competition.

The price guarantee to arrival is another costly marketing practice which originated logically enough but which has since, through competition, been abused. This

means that if a customer purchases sugar to be delivered in so many days and before delivery the price goes down, he is billed at the lower price. The two Pacific coast refineries are responsible for originating this practice. Today cane and beet refiners, because of competition, maintain what they call "warehouse stocks" in the various cities and towns where their sugars are distributed. The cost of warehousing, insurance, etc., is borne by them. Several years ago it was the practice of the cane refiners to distribute nearly all of their sugar by direct shipment to the buyers in carload quantities. At that time, however, the Pacific coast refineries found that they could not meet the competition of the Gulf and Atlantic coast refineries with sales throughout the central parts of the United States because of the extra time required for delivery. A jobber or wholesaler could purchase from the Gulf, receive delivery within a few days and resell to his retailer customers immediately. If, however, he purchased from a Pacific coast refiner and the price declined before the sugar reached him, he was out of luck. Hence, since the Pacific coast refiners had to market in this territory, the only method by which they could overcome their disadvantage was by guaranteeing their sales against declines. And just as one rotten apple sooner or later ruins the whole barrel, this practice has spread and infected the whole market.

It is primarily because of these two practices, bookings on advance notices and guarantees against declines, that the average price received by the refineries is considerably less than the daily average of refined quotations. I have not the figures for 1939, but for 1937 the daily average of quotations was $94.88 a ton, while the average price received by the standard cane sugar refineries was only $89.16 a ton—a loss of $5.72 a ton. In 1938 this loss was $3.44 a ton. Because of these practices a fluctuating market, either up or down, works out as a rule to the disadvantage of the refiner. If the price advances, his customers book at the old price and to supply them, he must buy raws at the advanced price. When it declines, he is usually stocked with sugar refined from raws purchased on a higher basis.

Other general practices, all for the buyer and against the interests of the seller, such as the four-payment plan, differential routes, arbitrary prepays, etc., might be explained but are scarcely important enough to dwell on here. When it comes to demoralizing marketing conditions these are "small change" compared to what has been termed the secret concession system. This was the practice by individual refiners, both beet and cane, of making sales to individual customers or groups of customers on secret terms or prices more favorable than those offered to the general trade, instead of selling to all on openly announced terms and prices. Along about the middle twenties, marketing conditions became particularly bad, and at that time secret concessions were given consisting of such practices as simple price rebates; payments to customers of brokerage fees; storage charges and advertising costs which were never incurred; the substitution of higher priced goods than those actually billed; delayed billing; free trucking; allowing buyers to increase bookings after a price advance was in effect; plus many others. In 1928 the cane refiners attempted to remedy this situation through the formation of the Sugar Institute, under which organization a code of ethics together with rules and regulations whereby discriminatory practices would be discontinued were mutually adopted. Unfortunately, although the matter was first taken up in Washington, this organization was declared technically illegal and today the refiners are under an injunction pre-

venting them from regulating under concerted action the sales ethics of their business. The concession system without necessarily discriminatory sales has again crept into the marketing of sugar, perhaps in an even more subtle form than ever before.

Although the marketing of sugar is at present in a decidedly unhealthy state, the opposite was the case fifteen years ago. The present and recent status of the market has been brought about by a change in conditions. During and after the first World War the cane sugar refiners sold much sugar to Europe. In 1922 they processed and re-exported 882,000 tons. This business has all but disappeared. Offshore whites have made a dent in their business to the tune of about half a million tons. During this same fifteen-year period beets have expanded by six to seven hundred thousand tons. To be sure, increased consumption has offset to some extent these losses but the net result has been a decrease in the domestic refining business by about 20 per cent. This explains why the cane refineries have made such strenuous efforts to obtain legal restrictions on offshore whites. These sugars not only take business from the refiners but since they are sold at a discount in the cane refiners' natural territory they have a very demoralizing effect upon the market.

On account of their loss in business the cane refineries at present are operated at about 60 per cent of their capacity. The cost curve of refining dips sharply with an increased melt. The out-of-pocket cost of refining additional sugar is very low—not much more than the cost of the containers. It is natural, therefore, that both the administrative and plant departments of the refineries should exert heavy pressure on their sales departments to market additional sugars.

The sale of beet sugars has contributed its share to the confusion. Because of the expansion of beets their companies have been compelled to blast their way into already overcrowded markets. The quota system has aggravated the situation. Hawaiian quotas can be filled by merely shipping raw sugar to the mainland but a beet company in order to fill its allotment must actually sell its sugar. Otherwise its rights are lost, at least so long as the present quota system prevails.

Another factor having a bad influence on marketing conditions has emanated from the brokerage system. Almost all refined sugar is sold through brokers who are quite but not entirely independent of the refiners. As compensation, brokers usually receive about 5 cents a bag or a dollar a ton. Some years ago an Eastern refiner attempted to sell his sugar direct without the use of brokers but this proved a dismal failure. It is now generally accepted that the brokerage system is the most economical method of securing sales. Since the brokers' earnings depend entirely upon the quantity sold, regardless of the price, it is natural that, in their efforts to sell, they at times overlook the interest of the refiner, who actually pays them their commission.

With symptoms such as these, is it any wonder that the patient is pretty sick? Refiner *A,* be he beet or cane, finds through his broker that he can sell a few thousand bags in the territory of refiners *B, C,* and *D* perhaps five hundred miles from his home base. Figured as additional business this is profitable, but does it help him? Not at all, since refiners *B, C,* and *D* in order to maintain their distribution, must forthwith ship their sugars five hundred miles into the territory of refiner *A.* Perhaps the first sale was obtained by granting a concession and so the second sale is made at even a larger concession and the game goes merrily on. Beet sugar pro-

ducers expand and sell sugar in the Eastern states, even in New England, all of which has been considered the territory of the Eastern refiners. The Eastern refiners retaliate and sell more sugar in the Mississippi Valley, thereby forcing more beet sugar East.

As long as quotas are excessive and more sugar is being offered than can be sold, marketing conditions are certain to be bad.

In the light of this picture, which perhaps is not quite as hopeless as has been painted, let us consider our own marketing problems. Honolulu Plantation Company refines its own and Waimanalo's sugar. The local demand is first filled and what remains is shipped and sold at present to a chain store in Los Angeles and the Northwest. As with all offshore sugar, that which is marketed on the mainland is sold at a discount. Eight Hawaiian plantations sell their crops, totalling about 100,000 tons, to the Western Refinery in San Francisco on the basis of the New York market price for raws, less the difference between the cost of marketing the same in New York and the cost of marketing in San Francisco. At present this deduction is $3.50 a ton.

All the other plantations sell their sugars, except for small amounts sold at the plantations, through C. and H. This refinery, which is entirely owned by the plantations selling through it, is operated on a cooperative basis. It handles about 85 per cent of the Hawaiian crop. Some of the sugar is refined at its plant at Crockett, other sugar is refined for its account in New York by an Eastern refinery and the remainder is sold in New York as raws. From the gross proceeds which C. and H. receives from its sales of refined and raw sugars, C. and H. deducts all of its expenses plus 6 per cent on its capital and pays the balance to the plantations pro rata in accordance with the tonnage sold. The 6 per cent deducted is also paid to the plantation stockholders as a dividend. It therefore follows that C. and H. serves as the marketing agency for four fifths or more of the sugar produced in this Territory and since C. and H. is a refinery, a major portion of the Hawaiian sugar industry is directly concerned with the marketing problems of refined sugar.

The plantations now owning C. and H. did not start this refinery as an enterprise for profit in itself but were compelled to establish it in order to assist in the marketing of their sugars. Prior to 1904, when C. and H. was incorporated, a portion of their crops was sold to a refinery in San Francisco and the remainder had to be shipped by sailing vessels around Cape Horn or transshipped by rail across lower Mexico and sold to Eastern refineries. This was far more expensive than shipping to San Francisco. The negotiations for a yearly contract with the San Francisco refinery became deadlocked, the representatives of Hawaii believing that the deduction demanded from the New York market price for raws was excessive, even though it was less than the additional cost required to ship sugar to the Atlantic seaboard. Hence it was decided to build an Hawaii-owned refinery at Crockett.

C. and H. purchased such sugars as it could sell as refined at $5.00 off the New York raw basis. The remainder of the sugars of the C. and H. plantations was not sold through C. and H. as is done at present but was sold direct by the plantations to Eastern refiners at a discount, usually about $2.00 per ton off the New York market price. Its profits were satisfactory and instead of distributing these as dividends they were used in paying off its indebtedness and expanding its plant to

meet the increased demands of the Pacific coast. With the rapidly growing population of western United States, it was believed that C. and H. would soon be able to refine and sell all of the crops of its plantations and its capacity was increased accordingly. This became particularly desirable on account of the excessively high freight rates resulting from the first World War.

In 1920 for the first time in the history of our sugar industry, all of the Hawaiian crop was shipped to San Francisco. That year, however, was a sad year for C. and H. The price of raw sugar soared to unprecedented heights in the spring and summer of the year when a major portion of the Hawaiian crop is being marketed. In May it reached a peak of over $470 a ton. Under the contract, C. and H. had agreed to purchase the sugar at $5.00 off the New York raw basis but could not dispose of the refined until months later. At the close of the year the price of raws was but a little over $100 a ton. The result was obvious. Sixteen years of savings, plus most of the original capital were wiped out. C. and H. had to be financially reorganized and to prevent a repetition of the result of 1920 it was reorganized on the present cooperative basis. During the two decades that C. and H. has been operated as a cooperative the plantations marketing their sugar through it have received on an average $1 or $2 a ton more than those plantations selling their sugar to the Western. In recent years, however, the returns on a comparative basis for the C. and H. plantations have not been as favorable. This is on account of another change in conditions.

The western part of the United States is obviously the natural market for Hawaiian sugars. Increasing the capacity of the C. and H. plant at Crockett so that it could refine all of its Hawaiian crop was logical. Three plants might have been built by adding one on the Northwest and one in Southern California, but at that time practically all Hawaiian shipping was direct to the San Francisco bay region and the unit cost of building and operating one large plant was considerably less. Other conditions which could not have been foreseen have altered the situation. The first of these was the increase in the Hawaiian crop from about 600,000 tons in 1920 to roughly a million tons today. Philippine whites have also cut into the Pacific coast markets to the extent of about 50,000 tons. The third and most important reason of all is the expansion of beets, particularly in the West. During the last fourteen years domestic beet production has increased from 800,000 tons to 1,450,000 tons. In 1926 the beet production of California was 68,000 tons while last year it was 451,000 tons. The increased demand in the West has been filled by other sugars. C. and H. sales of refined in the eleven Western states were slightly less in 1939 than they had been sixteen years previous.

The actual decrease, however, in the sale of Hawaiian sugars on the Pacific coast is greater than indicated. For many years C. and H. sold from 50,000 to 75,000 tons of raw sugar to the Western which in turn refined and marketed it in the West. This, however, was discontinued in 1933 when it was felt inadvisable for C. and H. to furnish its competitor with ammunition for use in its most desirable market. In order to sell its refined, C. and H. shipped sugars farther and farther East. By 1929 its inventories of refined sugars which it was unable to sell became so large that the practice of selling raw sugars to Eastern refineries was once again resumed and has been continued since then.

However, it was apparent that selling raws to Eastern refiners who in turn

marketed these same sugars as refined in the river territory in competition with C. and H. was not entirely sound. It was also considered desirable to attempt to establish a permanent home market for our sugars rather than depend upon our competitors. For this reason, five or six years ago negotiations extending for a couple of years or so were carried on by C. and H. looking towards the purchase of an Eastern refinery. Also, since each refinery considered had its own established distribution, it was believed that the removal of the pressure of the C. and H. sugar which had been squeezed out from the West would have a desirable effect upon general marketing conditions. Unfortunately, for one reason or another, all of these negotiations fell through. As a last resort two years ago, C. and H. entered into an agreement with an Eastern refinery under which the latter agreed to purchase our excess raws and also refine a portion of them for the C. and H. on a tolling basis. With this tolled sugar, C. and H. has entered the Eastern refined market where it is selling something over 100,000 tons annually. This arrangement is not entirely satisfactory since the only customers C. and H. can obtain are those that have been served by other Eastern refineries and this has resulted in retaliatory moves on their part.

Therefore, although the markets of Honolulu Plantation Company and the so-called Western plantations seem fairly secure, the present market of the C. and H. plantations is not entirely satisfactory and the indications are that it will become worse. The plant at Crockett has an annual capacity of about 800,000 tons but C. and H. can only sell 550,000 tons as refined and 100,000 tons of this amount is tolled in the East. Roughly the distribution of the 550,000 tons is about 200,000 tons a year in the West, another 200,000 tons in the river territory and the remaining 150,000 tons in the East and Northeast. With the large overhead costs of its refinery at Crockett, further reductions in the melt of that plant would prove expensive. And yet, with the expansion of beets, more of our sugar is being forced out of the Western market and with the substantial increase in shipping rates from Crockett through the Canal, maintaining the present melt is well-night uneconomic.

The logical solution seems to be the purchase of an Eastern refinery with a distribution large enough for our excess sugars and a reduction in the size of our plant at Crockett. We might then be able to largely withdraw from the river territory which is our most expensive market. The areas most readily served from New York, Philadelphia and Baltimore consume almost half of the white sugars consumed in the United States and because of freighting problems these areas are unattractive to beets. However, the purchase of an Eastern refinery has its complications.

A solution that is often given is that of refining at the plantations as Honolulu Plantation Company does or building one or more refining plants here in Hawaii. Without the existing legal restriction on shipping refined sugar to other parts of our country, which will certainly be removed some day, the advantages of Island refining appear obvious—a lower refining cost plus the ability to ship to any port rather than first to Crockett and then elsewhere. Furthermore, we would be adding another industry to Hawaii which is highly desirable. The major problem is not, however, a reduction in refining or freighting costs but the selling of sugar without breaking down the whole sugar price structure. C. and H. today could refine all of its sugar but simply could not sell it.

And it is open to argument that refining in Hawaii would actually result in increasing our net proceeds. With a plant already at Crockett and its existing overhead and organization, its out-of-pocket refining costs are probably much less than the costs, including additional capital charges, of refining here. Quality is of utmost importance and this would be difficult to maintain with plantation refineries. A reputation for poor quality might prove as expensive as it has for beets. Then too there would be the problem of producing the 34 grades marketed in 135 different forms and sizes of containers.

Freight savings are also not as simple as they appear on the surface. To be sure, we could ship to the Northwest or Southern California direct. But our sugars do not pay the freight from Crockett to Seattle or Los Angeles. San Francisco being a basing point, these freights are added to the price. If we shipped any quantity of refined direct, in all probability beets would establish other Pacific coast ports as basing points and our freight savings would disappear. We could refine here and ship direct to the Gulf for distribution in the river territory but that is our most unfavorable market. Also, supplying areas from Hawaii which are now supplied through Crockett would decrease the melt at our present plant. It would be a robbing-Peter-to-pay-Paul proposition.

Finally, there is the grave question as to whether sugars refined in Hawaii, regardless of quality, would not have to be sold at a discount as has always been the case with all offshore refined sugars and with all beet sugars. This could only be determined by the old method of trial and error and if it proved an error, more than the amount invested in Island refining would be lost. The day may come when refining in the Islands will fit into our general marketing picture, as it seemed to four years ago when the purchase of an Eastern refinery was being considered. Today, however, even without the legal restrictions, it would prove a serious mistake.

And so after having taken you on quite a tedious, rambling trip exploring regions beyond our horizon of the cost of landing raw sugar at market, we have returned home once again. And as is always the case, we are mighty glad to be back in Hawaii Nei. In this other field—the price we receive for our sugar—we find much confusion, bitter antagonism and open hostility. Here we have the opposite—all working together and helping each other in an endeavor to reduce the cost of our product directly by eliminating unnecessary labor or material or indirectly by increased yields and recoveries.

Undoubtedly our most vital cooperative policy is that of virtually selling as a unit, rather than in competition. This cooperation in selling our sugar is and always has been vastly more important, not only to the C. and H. plantations, but to all others as well, than the combined cooperation in all other branches of plantation activities. Its discontinuance would prove fatal to our industry.

Canton Island

By R. H. Van Zwaluwenburg

The Clipper plane service, now operated between Honolulu and New Zealand by the Pan American Airways Company, brings into sharp focus the importance of Canton Island as a quarantine station at which to intercept undesirable insects which threaten Hawaii from the South Pacific region. With an entomologist of the Hawaiian Sugar Planters' Association stationed on Canton, a second "filter" (the other being at Midway) now supplements the official quarantine services guarding this Territory against new insect pests.

Canton Island lies about 1670 air miles south-southwest of Honolulu, at about 171° 43′ west longitude and 2° 49′ south latitude. It is a coral atoll—a strip of land encircling a lagoon—and in outline it resembles a porkchop. The land strip, characteristically higher along the ocean shore than on the lagoon side, varies in width from about 75 yards to one third of a mile, and is about 27 miles around. The island measures some nine miles by four, and its highest point is not over 25 feet above the sea.

The outer shore slopes abruptly to the fringing reef, while on the inner shore the slope to the lagoon is gentle, ending in a sandy beach or in low ledges of overhanging coral. Along the lagoon shore are a few small tidal pools, and on the southern part of the island are two large ponds formed by the caving in of undermined coral. Along its outer rim especially, much of the island is piled with large pieces of broken coral tossed up by high seas which now and then break across the narrower parts of the land and pour into the lagoon. In other parts there are extensive areas of bare, unbroken rock; still other parts of the island are covered with sand, and there vegetation is at its best. Occasional fragments of pumice, worn smooth by wave action, are found here and there; they are not of local origin, but reached Canton probably after a long drift westward on the equatorial current.

The lagoon is relatively shallow and studded with coral heads and long, wall-like reefs. Because there are but three breaks in the surrounding land through which water can pass, the movement of water within the lagoon lags behind the ocean tides, and the difference between high- and low-water levels is much less there than outside. The water within the lagoon has a higher salt content than the sea water.

There is no fresh water on Canton and residents depend upon stored rain water. There is a great variation in rainfall from year to year. The records of the British station, which have been maintained continuously since September 1937, show the following total rainfall:

1938	8.71 inches
1939	18.47 "
1940 (first 5 months only)	30.25 " *

*Since this was written, R. R. Danner reports that the rainfall during 1940 totalled 69.3 inches; of this, over 18 inches fell during December.

The distribution of rain appears to have been fairly good during the past year and a half. Temperatures show comparatively little daily or seasonal range; maximums are in the lower nineties. The island lies within the equatorial belt of relative calms; the highest wind velocity recorded is 30 m.p.h.* Prevailing winds are from the east-southeast.

Canton is the largest of the Phoenix Group and, although perhaps visited from time to time by Polynesian seafarers, was probably never long inhabited. The exact date of its discovery in modern times seems to be unknown. The island was not marked on charts published in London in 1791, but is named in a report filed with the United States Secretary of the Navy in 1828. Early in the nineteenth century it was known variously as Mary, Balcout, Balcut or Swallow Island. Its present name became current after the whaling ship *Canton,* of New Bedford, struck and

Fig. 1. Map of Canton Island adapted from Bryan.

sank on its western coast in March 1854. During the eighties an English company worked the guano deposits on the east side of the lagoon. (The "stone pier" shown on the accompanying map marks the location of the guano diggings.) In 1916 a British trading company took a long lease on the island, but appears to have done

*H. K. Graves states that in December 1940 unprecedented winds from the west attained a velocity of 55 knots an hour.

nothing further than to plant some coconuts. When trans-Pacific aviation gave the island importance American and British claims came into conflict. These have now been adjusted on the basis of joint occupancy for a specified term of years. At present there are over 50 residents on Canton, including the P.A.A. personnel and a smaller group at the British settlement. The airport is fully equipped with power plant, machine shop, radio station, personnel quarters, water storage facilities, a small hospital and a modern hotel. Planes alight and take off at Canton on the lagoon; they are moored at the end of a pier some 50 yards from shore.

The native flora of Canton is comparatively simple. E. L. Caum has arranged the known species as follows:

Graminae
- *Digitaria pacifica* Stapf
- *Eragrostis whitneyi* Fosberg var. *typica* Fosberg
- *Lepturus repens* R. Brown

Palmae
- *Cocos nucifera* Linnaeus

Nyctaginaceae
- *Boerhaavia diffusa* Linnaeus

Aizoaceae
- *Sesuvium portulacastrum* Linnaeus

Portulacaceae
- *Portulaca lutea* Solander

Lauraceae
- *Cassytha filiformis* Linnaeus

Zygophyllaceae
- *Tribulus cistoides* Linnaeus

Simarubaceae
- *Suriana maritima* Linnaeus

Tiliaceae
- *Triumfetta procumbens* Forster

Malvaceae
- *Sida fallax* Walpers

Convolvulaceae
- *Ipomoea pes-caprae* (Linnaeus) Roth
- *Ipomoea grandiflora* Lamarck

Boraginaceae
- *Cordia subcordata* Lamarck
- *Tournefortia argentea* Linnaeus

Rubiaceae
- *Morinda citrifolia* Linnaeus

Goodeniaceae
- *Scaevola frutescens* (Miller) Krause

Whether or not the coconut is "native" to Canton may be debatable; certainly all of the few specimens there today were planted within recent times. Five large

Fig. 2. Canton Island settlement as seen looking southwest from the lagoon. British settlement next to coconut trees; P.A.A. buildings center and left.

Fig. 3. View from lighthouse tower, Canton Island, looking south-southeast toward lagoon. British settlement center; P.A.A. hotel extreme right.

trees standing near the British settlement and two others at the north end of the island are believed to have been planted about 1916. An extensive planting was made in 1937 west of the lagoon and, although the plants have made little growth, many survive.

Coconuts excepted, the island's most conspicuous vegetation consists of clumps of Cordia (kou), Tournefortia (tree heliotrope) and Scaevola bushes. These are often 10 to 15 feet tall, and usually have many dead, bare branches above the green growth nearer the ground. A nearly solid growth of Scaevola, occupying the width of the island, extends for about two miles along the southwest coast. As a probable result of the good rains of the past year or more, the richer parts of the island are at present covered with an excellent growth of Sida, Portulaca, Triumfetta, Boerhaavia and bunch grasses (Lepturus and Digitaria). In less favorable spots Triumfetta often occurs alone. Eragrostis and Sesuvium occupy low hollows. Suriana, a woody shrub, usually grows very close to the ground, but in one case a clump of it attains a height of some ten feet. Near the guano diggings is growing the single specimen of Morinda (noni) at present known on the island. There too, occurs a white-flowered Ipomoea, while another species, the well-known beach morning-glory, occurs on the lagoon shore near the British station. Cassytha is a vine-like parasitic plant suggestive of dodder. It is probable that the thriving state of the native vegetation, as it existed during the latter months of 1940, is not the usual condition on Canton. The first P.A.A. construction force to arrive in the spring of 1939 reported that the area now waist high in Sida and associated plants was then practically a desert.

The Pan American is doing extensive planting, using native materials as well as promising foreign plants like seagrape and ironwood. What effect a prolonged drought will have on these plantings remains to be seen, but it is hoped that many of them will by then be sufficiently established to survive water shortages. Storage facilities for water are not adequate to care for large numbers of plants should prolonged droughts occur.

Importations of soil from Oahu have resulted in the recent establishment on Canton of several weeds such as *Emilia sonchifolia,* three species of Euphorbia, *Leucaena glauca,* nutgrass and amaranth. A few grasses, including bermuda grass, have also gained a foothold in the same way.

The new arrival at Canton is apt to notice first the fish which crowd about the wharf where the planes are moored. They are a spectacular feature of the lagoon life, and their almost infinite variety would require a lifetime for thorough study. Despite the dynamiting which was necessary to prepare runways for the planes, the fishing in the Canton lagoon is still incredibly rich. Ulua, redsnapper and rock cod are a few of the species in the lagoon, while outside are also to be had barracuda, yellow-finned tuna and many other fish. Sharks are abundant in both lagoon and ocean; known locally as "sand sharks" they grow to a length of six feet or more. Small ones venture into shoal water within a very few feet from the shore. They appear inoffensive under ordinary circumstances; at any rate, Canton residents commonly swim in the lagoon where these sharks are frequent.

Marine birds form nearly all of the island's numerous bird life. Nesting in the higher clumps of kou and tree heliotrope are two or more kinds of gannets (booby birds), while the frigate birds keep more or less apart in lower growths of Suriana

Fig. 4. Scaevola clumps, southwest coast of Canton; Triumfetta in foreground.

Fig. 5. Scaevola thicket, southwest coast of Canton; dead branches are characteristic of nearly all of the shrubs.

and Scaevola. The blue-faced booby lays its egg on bare ground without benefit of nest. The white "love tern" makes no nest, and is inclined to lay its egg on the precarious pinnacle of a rock. Loud squawks from the less common bos'n bird are meant to warn intruders from the rock ledges under which that bird nests. Many of the birds, particularly the gannets, are so tame that they are easy subjects for the camera. Long-billed curlews frequent the reef at low tide, while a variety of the familiar golden plover busies itself in the grass, the only one of the birds, apparently, to show any interest in insects.

Wherever there is good cover, the small, ground-nesting Polynesian rat is present in astonishing numbers, and it occurs more or less all over the island. Besides robbing domestic foodstuffs, it feeds on vegetable food such as the bark of twigs, and the fruits and flowers of Scaevola, climbing well above ground in daylight with little show of fear.

From the standpoint of our quarantine it is the insect fauna that is of greatest moment. Not only is it important that we know what insects now on Canton should be guarded against, but also that we be able to recognize if any dangerous additions to the fauna occur there in the future. Much of the writer's time from July 25, 1940 to early October was devoted to a survey of the insect life. As a result of this and the earlier work of D. B. Langford, a list of over 60 native and immigrant species of insects and related forms was compiled. Since then, R. R. Danner has added considerably to the list, but it seems probable that the completed total will not exceed 100 species.

At present there are few insects on Canton which would be undesirable additions to the Hawaiian fauna. The most important of these is the noctuid moth *Prodenia litura* (Fabricius), known, with a long list of economic food plants, from many Pacific islands. Another is an unidentified cicadellid leafhopper associated with Boerhaavia; this belongs to a distinctly undesirable group of insects. Still another is the arctiid moth *Utetheisa pulchelloides* Hampson, the caterpillars of which make Tournefortia foliage unsightly by their feeding. Attached to kou is a large noctuid caterpillar, *Achaea janata* (Linnaeus), belonging to a group some species of which, as adults, damage citrus fruits by piercing them with the proboscis; this is a species which would most certainly not be welcome in Hawaii. Practically all of the insects boarding the planes at Canton are flies, some of them already here in Hawaii, and none of economic importance.

The absence of the usual insect-parasite complex is one of the most striking entomological features of Canton. A species of Baeus, a hymenopteron presumably parasitic in spider eggs, was once collected by Mr. Langford in sweeping low herbage, but has not been found since or bred from any of the numerous spider eggsacs collected for observation.* With this probable exception there appear to be no parasites of insects. There are none of the hymenopterous or dipterous parasites usually associated with a numerous and varied population of leaf-feeding caterpillars. The non-native scale insects, brought in on imported plants during recent years, likewise appear to be without insect parasites.

Canton is almost unique in having at present no mosquitoes, and apparently no

*The Baeus from Canton, identified by Dr. F. X. Williams, seems to be identical with the species introduced into Hawaii in 1939 from California (*Baeus californicus* Pierce). There is good reason to believe that the specimens credited to Canton were not actually collected there, but instead were accidentally taken there in laboratory glassware from Honolulu.

Fig. 6. Abandoned guano diggings on east side of lagoon. Lepturus grass in foreground, Scaevola bushes in middle distance and Tournefortia in rear. Low areas often have Eragrostis grass.

Fig. 7. Blue-faced booby, south of P.A.A. settlement, Canton. Most of the ground is covered with Triumfetta, with scattered bunch grass and Sida.

fleas. Mosquitoes are very numerous at Noumea, the first P.A.A. base south of Canton, and Culex and Aedes adults are almost constantly being found dead in planes arriving at Canton from the south. In bringing planes to the mooring at the landing float one or more hatches must be opened before any contact is made with the shore. Therefore keeping the island free from mosquitoes of necessity depends very largely upon the efforts of the flight stewards, and the care with which they spray the planes while en route. It is a pleasure to record their active interest in this important matter, and the thoroughness with which they spray the planes approaching Canton. Mosquitoes occur in both New Caledonia and Hawaii which could breed readily on Canton in rain barrels and in empty containers discarded over wide areas near the airport settlement. Tidal pools would probably not support wrigglers of these species because of the high salinity of the lagoon water with which they are renewed at each tide.

Although there are on Canton three dogs which certainly were well stocked with fleas when brought to the island, search for these parasites during the writer's stay was uniformly unsuccessful. Nor did any of the rats appear to harbor fleas. Rats are often seen to scratch themselves, but this seems due to lice and perhaps other parasites, and not because of fleas. Perhaps the scarcity of organic matter in the sandy soil does not afford enough food for development of flea larvae. That their failure to multiply is not due to lethal soil temperatures was demonstrated by soil readings made during the hottest hours of an August day.

There are numerous short references to Canton scattered widely in a variety of publications, but the only articles known to the writer which are at all extensive are the following:

Bryan, E. H. Jr., 1940. The meager vegetation of Canton Island. Paradise of the Pacific, 52: 26–27, 2 figs.

Gardner, Irvine C., 1938. Crusoes of Canton Island. The National Geographic Magazine, 73: 749–766.

Fig. 8. American Clipper moored on lagoon, Canton Island. The landing float some 50 yards from shore is at the end of a pier, part of which is visible at the right.

Fig. 9. S. S. Admiral Day, Canton Island, September 21, 1940. This ship ran fast aground on the northeast coast of the island the night of September 18, and was abandoned 12 days later after water had flooded the engines. According to recent reports, the Admiral Day has now broken up and very little of it is visible on the reef.

Observations on Insect Pests in Samoa Which Are Not Yet Known to Occur in Hawaii

By O. H. Swezey

While accompanying E. C. Zimmerman of the Bernice Pauahi Bishop Museum on an entomological exploration trip to Samoa, May 27 to September 5, 1940, considerable definite information was obtained on dangerous crop pests which are not now present in Hawaii. Some of these would be very destructive in Hawaii if they should gain a foothold here and become generally spread. It is to our advantage to know of their habits and of their presence in this neighboring group of islands, which is now only five days away by steamer. Continuous vigilance should be maintained to prevent these pests from reaching our shores.

These pests are here listed according to the crop or food plant which they particularly infest. Names have already been secured for most of them, but are still lacking for a few. In the list are 70 species, a dozen of which were not previously recorded from Samoa.

Sugar Cane

Sugar cane is not grown to any great extent in Samoa, there being only small patches in the villages. The tops are used to thatch the native house (fale), and several varieties, mostly with small diameter stalks, are thus used. A larger red variety is used for eating.

Perkinsiella vitiensis Kirkaldy

This species of leafhopper is closely related to the sugar cane leafhopper in Hawaii. It occurs also in Fiji, where it is considered the transmitter of the Fiji disease of sugar cane. This disease is known in Samoa also. The leafhoppers were found to be not very destructive in Samoa, although occasional neglected patches of cane showed very numerous egg-punctures in the midribs. The leafhoppers themselves were scarce, both as adults and as nymphs. Two kinds of egg parasites were reared from leafhopper eggs. The rarer one was *Paranagrus optabilis* Perkins, and the more abundant one was *Ootetrastichus beatus* Perkins. The round exit holes where the latter had issued were often very abundant. Counts of these exit holes in 10 leaves gave a range in number from 20 to 65 per leaf.

Neomaskellia bergii (Signoret) (Figs. 1 and 2)

The widely distributed (Samoa to Java and Mauritius) sugar cane aleurodid was usually found in small colonies. Occasionally there was a larger colony which almost covered the under surfaces of many leaves in the same stool of cane. No parasites were found, but on two occasions several caterpillars of *Cryptoblabes proleucella* Hamps., a phycitid moth, were found feeding on the aleurodids. The caterpillars fed beneath a thin web. Several moths were reared. One colony was found on *Miscanthus*.

Cosmopteryx dulcivora Meyrick (Fig. 4)

The midrib leafminer is the slender yellow larva of a tiny moth. It bores for a considerable distance longitudinally in the midrib, often in a zigzag manner, so that the midrib is rendered useless and turns a reddish color. Affected leaves are usually conspicuous. Larvae and pupae were collected, but only one moth was reared. This species occurs also in Fiji. It was not recorded in "The Insects of Samoa."

Melanitis leda solandra (Fabricius)

This butterfly in one or another form is distributed widely in China and Malaya, and also in the Philippines, Guam and other Pacific islands. Its large green caterpillar was commonly found on the cane plot of the Experimental Farm at Taputimu, Tutuila. The beautiful green chrysalids were also seen on the leaves, and the butterfly was reared. It was also reared from *Miscanthus,* the caterpillars being found on this plant in several localities. It is reputed to feed also on corn and other grasses.

Corn

Scarcely any corn is grown in Samoa, hence there was little opportunity for observing insects associated with it. Small patches were seen in only two localities.

Phytomyza spicata Malloch

The corn leafminer is the maggot of a tiny black fly, which is known in Fiji and Guam. Very little evidence of it was seen on corn in Samoa. It was very abundant on Job's-tears, and also found on *Miscanthus,* Bermuda grass, *Eleusine indica,* and no doubt could be found on other grasses. Chalcid parasites were reared on several occasions.

Marasmia trapezalis (Guenee) (Fig. 5)

This is the leafroller which I found so abundant on corn in Guam in 1936. It has a wide distribution in the tropical regions of South America, Africa and India, and also in Malaya and across the Pacific to the Marquesas. I did not find it on corn in Samoa, but did find it quite common on *Miscanthus.* A braconid parasite was reared from one lot of caterpillars.

Marasmia venilialis (Walker) (Fig. 3)

On one occasion this grass leafroller was reared from corn. It was very abundant on *Paspalum conjugatum,* Job's-tears and also on other grasses. This is another widespread leafroller, occurring in Africa, India, Australia, Solomon Islands, Borneo, Guam and Fiji.

Adoretus versutus Harold (Fig. 10)

This beetle is related to *Adoretus sinicus* in Hawaii, and has the similar nocturnal habit of feeding on foliage. Corn leaves showed results of their feeding. Many other plants, ornamentals, shade trees and forest trees were badly eaten by these beetles. This is the beetle whose larva, or grub, has been injurious to cane roots in Fiji.

Coconut

The coconut tree has many kinds of insects feeding on it in one way or another, the following six species of which do not occur in Hawaii.

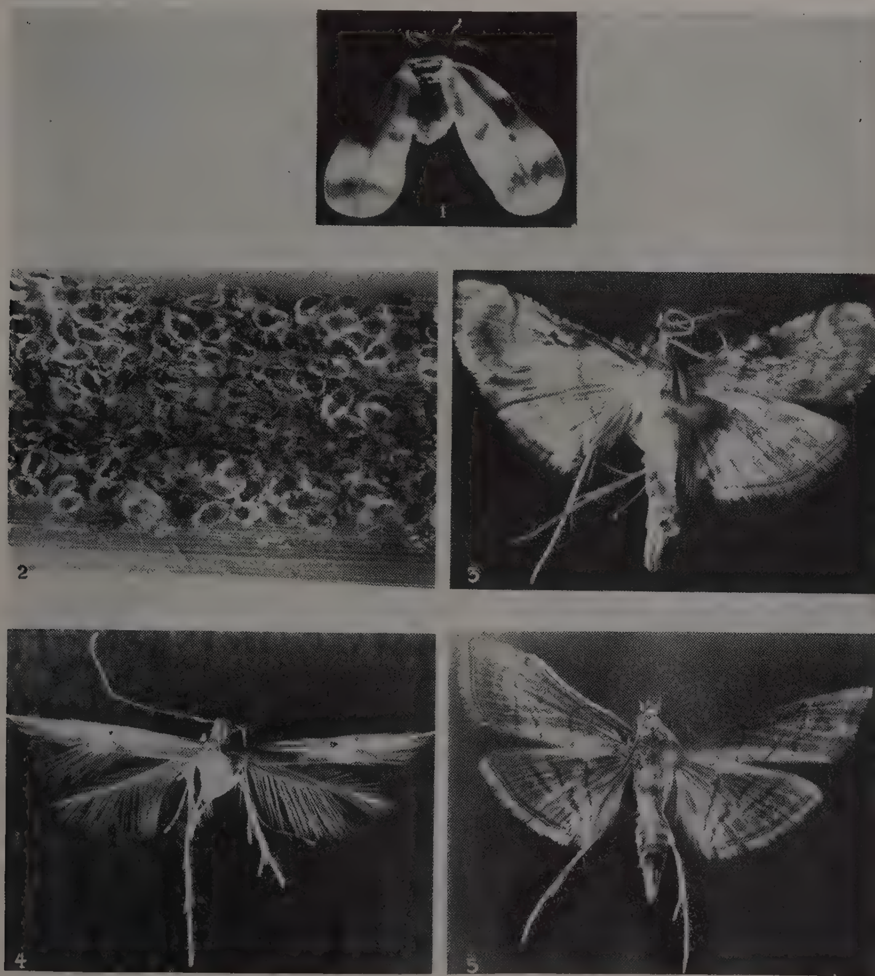


Plate 1

Fig. 1—*Neomaskellia bergii,* cane aleurodid. × 20. Fig. 2—*Neomaskellia bergii,* colony of young on cane leaf. × 6. Fig. 3—*Marasmia venilialis,* grass leafroller. × 4. Fig. 4—*Cosmopteryx dulcivora,* midrib miner of sugar cane. × 8. Fig. 5—*Marasmia trapezalis,* corn leafroller. × 3.5.

Oryctes rhinoceros (Linn.) (Fig. 6)

The large notorious rhinoceros beetle is very destructive to the coconut tree. The adult beetle feeds in the top where it makes large burrows among the soft tissues which results in very ragged leaves when they finally expand, and sometimes

causes the death of the tree. By methods of control the beetles are prevented from doing their worst damage, and badly injured trees are not particularly numerous at the present time. Their enormous larvae or grubs are found in and beneath rotten logs on the ground and in stumps. The best method of control is searching these out and destroying them. Traps are made by placing split coconut logs on the ground to attract the beetles for oviposition, examination being made at intervals, and whatever beetles or grubs found are destroyed. This beetle occurs throughout Malaya, Philippines, China, Siam and India. It is said to have been introduced into Samoa in 1910.

Promecotheca reichei Baly (Fig. 8)

The larvae of this beetle are leafminers. There are many related species in the various localities where coconuts grow. This species is known in Tonga and Fiji. It has blue elytra with anterior third yellow. We found its work in the coconut leaves of both young and also tall trees at the U. S. Naval Station, Pago Pago. The mines were very abundant in the leaves. In some leaves cut from a tall tree every leaflet had mines, from one to six per leaflet. All were old mines, none having living material. At another time, of a lot of mines examined, 83 per cent had had parasites issue from them, as shown by the tiny round exit holes in the leaf. No living material was found in any examination of mines. Perhaps this beetle and its parasites are seasonal, and this may have been the wrong season as we were at Pago Pago during August. No evidence of the work of this beetle was seen on any other part of the island, nor on Upolu.

At the naval station other kinds of palms were also affected. The mines were found in leaves of the royal palm, *Pritchardia pacifica,* and two other palms. The mines show up as dead streaks in the leaflets.

Graeffea crouani (Le Guillou)

This is a green, elongate, long-legged insect commonly called the walking-stick insect. It is often commonly found on coconut leaves where it feeds, eating large notches in the margins of the leaflets and giving the leaves a ragged appearance. It occurs also in Fiji and Tonga and is sometimes recorded under the name *Graeffea coccophaga.*

Pseudococcus cocotis (Maskell)

A mealybug which occurs especially on young coconut plants.

Agonoxena argaula Meyrick (Fig. 15)

A small buff-colored moth whose larvae feeding singly beneath a slight web on the underside of coconut leaflets produce short, narrow streaks of dead tissue where they have eaten off the under part of the leaf. All of the mature leaves are spotted with these streaks. Soon after the new leaves are fully expanded, the small caterpillars begin feeding on them. The other palms mentioned above are also somewhat eaten by these caterpillars. On the island of Upolu, two native palms in the mountain forests had their leaves very much eaten. A braconid parasite (*Apanteles*) was reared from cocoons of this moth. This moth occurs also in Fiji and the Ellice Islands.

Trachycentra calamias Meyrick

Caterpillars of this medium-sized grayish moth were found feeding in the living tissues of the top of a coconut trunk where the rhinoceros beetle had been burrow-

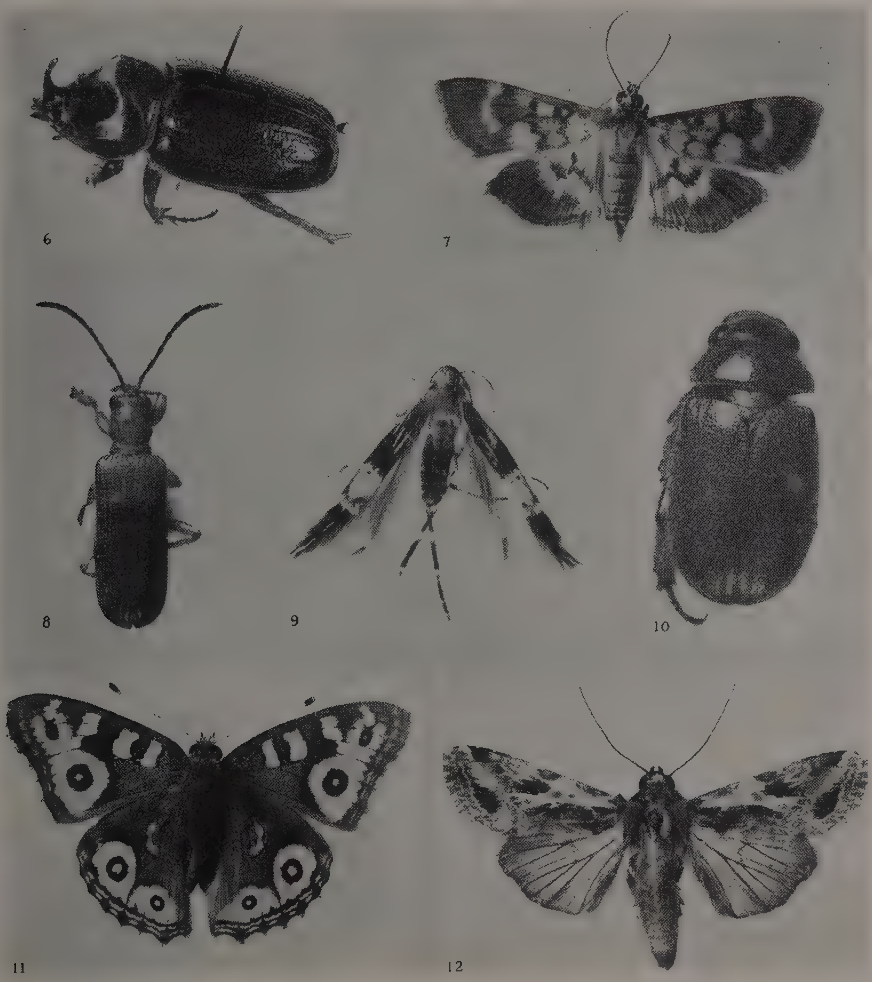


Plate 2

Fig. 6—*Oryctes rhinoceros,* rhinoceros beetle. × 1.5. Fig. 7—*Nacoleia diemenalis,* bean leafroller. × 3. Fig. 8—*Promecotheca reichei,* coconut leafminer. × 4.5. Fig. 9—*Cosmopteryx mimeticus,* nutgrass leafminer. × 8.7. Fig. 10—*Adoretus versutus,* Fijian cane root grub. × 7. Fig. 11—*Precis villida villida,* butterfly whose caterpillars were feeding on sweet potato. × 1.3. Fig. 12—*Prodenia litura,* taro moth. × 2.

ing also. Some of the larvae were feeding in the mass of rotten fibrous material of the dying tree. The older caterpillars were enclosed in elongate brown cases on which they finally place a covering of numerous overlapping fibers placed longitudinally. One end is eventually attached in a convenient place and transformation

to the moth takes place within. This moth was also reared from cases found beneath old banana leaf sheaths. One was also reared from a larval case beneath rotten bark of an *Erythrina* log. This moth occurs also in Fiji and Tonga.

Banana

Nacoleia octasema (Meyrick) (Fig. 18)

The banana scab moth is very destructive everywhere in Samoa. The caterpillars feed among the young bananas on the bunch, eating the skin of many, which gives them a scabby, unsalable appearance when mature. In many cases the caterpillars eat into the young fruits entirely spoiling them, the whole bunch often being ruined. Damage is checked by dusting with surphur at the proper time. Great quantities of bananas are shipped from Apia to New Zealand. In packing for shipment, all bananas are cut from the bunch in order to sort out and discard the scabby and injured ones, while the perfect ones are packed in cases. If this moth ever became established in Hawaii, similar methods would have to be resorted to for bananas shipped to California, instead of the present method of wrapping the whole bunch for shipment. This pest causes great losses to the growers in Samoa, and it occurs also in Fiji, Queensland and Java.

Cosmopolites sordidus (Germar)

This is a large black weevil about the size of the sugar cane beetle borer. The larvae feed in the base of banana plants. We did not find them common enough to cause significant injury. It occurs very widely in Brazil, West Indies, Queensland, Fiji, Guam, Philippines, and Java. In some of these places it is very injurious.

Prodenia litura (Fabricius)

Caterpillars of this moth feed to some extent on banana leaves.

Taro

Prodenia litura (Fabricius) (Fig. 12)

This widely spread moth was the worst taro pest we observed in Samoa. It is a pest the world around in the tropics, feeding on many kinds of cultivated plants. On taro the eggs are deposited in clusters of several hundred on the underside of the leaf. The young larvae feed gregariously for awhile, then scatter to nibble here and there, but eventually as they reach their full growth skeletonize the leaves so that only the main ribs are left. Such leaves are conspicuous in the taro patches, and at times a great deal of damage is done. Other plants on which I found caterpillars are: banana, tobacco, sensitive plant, and *Ipomoea pes-caprae*. A few caterpillars were found parasitized by *Euplectrus*.

Hippotion celerio (Linnaeus)

Another widespread moth occurring in Europe, Africa, India, Java, Borneo, Timor, Australia and Fiji. It is one of the smaller-size hawkmoths. The eggs are laid singly on taro leaves. A few of the green caterpillars were found in most taro patches, and they are said to sometimes defoliate the plant completely, and to feed on other plants related to taro.

Herse convolvuli (Linnaeus)

This is the morning-glory hawkmoth which is widely distributed throughout the Pacific islands, with the exception of the Hawaiian Islands where a related and

Plate 3

Fig. 13—*Sylepta derogata,* hau leafroller. × 2.5. Fig. 14—*Thiotricha strophiacma,* Terminalia leaf perforator. × 6. Fig. 15—*Agonoxena argaula,* coconut leaf moth. × 4. Fig. 16—*Acrocercops homalacta,* sweet potato leafminer. × 9. Fig. 17—*Pachyrhabda amianta,* bird's-nest fern moth. × 7.5. Fig. 18—*Nacoleia octasema,* banana scab moth. × 2.5.

closely similar species from America, *Herse cingulata* (Fab.), prevails. The caterpillars of both species feed on sweet potato leaves, this plant belonging to the morning-glory genus *Ipomoea.* The species in Samoa was found to be doing no appreciable injury to sweet potato.

Precis villida villida (Fabricius) (Fig. 11)

This butterfly was reared from black spiny caterpillars feeding on sweet potato leaves, though not abundant. It occurs also in Tonga, Ellice Islands, Swain's Island and Tokelau Islands. It has been previously recorded from the strand plant *Scaevola koenigii.*

Bedellia sp.

This is a very small moth whose larvae are leafminers in sweet potato. It is related to the sweet potato leafminer in Hawaii, but is a distinct species, as shown particularly by quite a different larva. It was not common. Parasites (*Apanteles* sp.) were reared.

Acrocercops homalacta (Meyrick) (Fig. 16)

This is another leafminer, larger than the preceding. It occurs also on morning-glory of various kinds, particularly on a large-leaved species with white flowers which is probably *Operculina turpethum.* It was quite abundant in the largest productive garden which we visited. It is very closely related to, and may possibly be identical with, a species (*Acrocercops prosacta*) recorded as a leafminer on sweet potato in India. A species of *Apanteles* was reared from mines.

Ercta ornatalis (Duponchel)

A small pyralid having green caterpillars which feed on the underside of the leaves. It was more common on several species of morning-glory.

Cassida strigula Montrouzier

A tortoise-shell beetle which feeds on morning-glory leaves as well as on sweet potato leaves. Common in places, but not enough for significant injury. It occurs also in New Guinea and Australia.

Beans

Nacoleia diemenalis (Guenee) (Fig. 7)

The bean leafroller with wide distribution in the tropics. The caterpillars feed between webbed-together leaves of several kinds of beans and are sometimes quite destructive. An *Apanteles* parasite was reared, also a small tachinid.

Acrocercops sp.

The bean leafminer, the same as was prevalent in Guam. It is very abundant on some kinds of beans in Samoa.

Acrocercops sp.

A different species of leafminer was found and reared from leaves of an unidentified wild bean vine. Sometimes there were two larvae in the same mine. They pupated in slight cocoons in the mines, whereas larvae of the other species issued to produce their cocoons on the surface of the leaf.

Jamides argentina (Prittwitz)

A beautiful blue butterfly whose larvae feed within buds and blossoms of *Vigna marina,* a yellow-flowered bean vine on the beach. One larva would destroy quite a number of blossoms.

Margaronia mysteris (Meyrick)
Phostria oconnori Tams

These two moths were reared from caterpillars feeding between webbed-together leaves of wild bean vines in the mountain forests. *Strongylodon lucidum* and *Mucuna gigantea* were both present, and it was not always possible to distinguish which of these vines was the host of the caterpillars collected. A tachinid maggot issued from one caterpillar. The first-named moth was described from the New Hebrides; the second from Samoa.

Brenthia catenata Meyrick

A small dark moth whose caterpillars were abundant and feeding on leaves of a wild bean vine, *Strongylodon* or *Mucuna*. Transformation took place in white spindle-shaped cocoons on the surface of the leaves.

Azazia rubricans (Boisduval)

A medium-size gray moth reared from green semilooper caterpillars on *Vigna*. Twenty *Apanteles* parasites issued from one caterpillar. This moth is recorded from Africa and India, and also from Java and other Pacific islands, but was not previously recorded from Samoa. Perhaps it has become established recently as it is not very abundant yet. It is a minor pest of several kinds of beans in India.

Green pentatomid bug (an undetermined species)

This large bug was found abundant on beans, as well as on other garden plants, and is sometimes quite injurious.

Cucurbits

Margaronia indica (Saunders)

This leafroller moth occurs on cucumber but was not common enough to be injurious. It is widely distributed in Africa and India, and in Malayan and Australian regions. We found it in Guam in 1936.

Agromyzid leafminer (undetermined)

A very small black fly was reared from mines in leaves of a wild cucumber. It was found abundant in several places. The puparia were formed within the mines, and figitid parasites issued from some of the puparia.

Epilachna 28-punctata (Fabricius)

This large phytophagous ladybeetle ranges from the Orient to Australia and the Pacific islands. It feeds on many plants, particularly the leaves of pumpkin vines which are sometimes entirely destroyed. The adults as well as the larvae feed on the leaves.

Aulacophora similis Olivier

This moderate-size leaf beetle was described from New Guinea. We found it common on squash and cucumber vines.

Green pentatomid bug (undetermined)

This large bug is often found on cucurbits as well as other garden plants.

Tobacco

Heliothis assulta Guenee

The caterpillars of this pretty, medium-size moth were very abundant on tobacco plants, every plant of the most pretentious planting which we saw had been injured, and daily hand picking had been resorted to. These caterpillars also attack green tomatoes. I reared two moths from caterpillars feeding on the green fruits of *Physalis minima,* closely related to our poha in Hawaii. Each caterpillar would require a large number of fruits for its maturity.

Prodenia litura (Fabricius)

Caterpillars of this moth were found on tobacco.

Guava

Dacus psidii Froggatt

This is the guava fruitfly. We found strawberry guavas infested with maggots, but failed to rear the adult flies, although it was undoubtedly this species. Fruit of the common guava was scarce, and we made no observations as to their infestation.

Spilonota holotephras Meyrick

This is a small fuscous-colored leafroller moth whose larvae infest the terminal twigs of the common guava. The new leaves are webbed together and eaten before they have expanded. This causes a setback to the growth of the twig and, as there are sufficient caterpillars to seriously check the welfare of the plant, the guava does not thrive well nor become so generally predominant as it does in many regions in Hawaii. This is the same moth which similarly affects the guava in Guam.

Papaya

Dacus xanthodes Broun

This fruitfly was previously reared from papayas, although we had no observations on it at this time. Fruitflies have also been reared from avocadoes in Samoa. There are also other fruitflies in Samoa. Malloch, in the "Insects of Samoa," records seven species altogether as occurring there, none of which is yet known in Hawaii.

Cacao

Hypsipyla swezeyi Tams

The larvae of this phycitid moth feed on seeds in ripened pods. The larvae are white and quite plump, and the moth is gray.

Grasses

Spodoptera mauritia (Boisduval)

Armyworms are quite abundant in places, as evidenced by their egg masses. Thirty egg masses were counted on a small citrus tree in a grassy lawn. There was no evidence of egg parasites. The caterpillars were not numerous in the grass, perhaps due to the large flock of poultry which daily ranged this lawn. At another place, egg masses were more numerous; there were 160 on one leaf of a young royal palm near a golf course. They were mostly old ones, and apparently egg

parasites had issued from most of them, as they had the appearance of *Laphygma* eggs in Hawaii after the parasite *Telenomus nawai* has issued from them. This moth has a wide range of distribution in the tropics. It has been recorded from Hawaii, but it was discovered recently that this record was a misidentification of *Laphygma exempta* (Walker).

Marasmia venilialis (Walker)

This is the same leafroller discussed under corn insects. It feeds on several kinds of grasses.

Marasmia trebiusalis (Walker)

This leafroller is closely related to the above, and is usually found on the grass *Oplismenus compositus*. An *Apanteles* parasite was reared from it.

Cosmopteryx mimeticus Meyrick (Fig. 9)

This pretty little moth is a leafminer in nutgrass (*Cyperus rotundus*), and has a wide range in tropical Africa, India, Australia and South America, and in New Guinea, Fiji and Malaya. It was commonly found in Samoa.

Sogata kirkaldyi (Muir)

Sogata eupompe (Kirkaldy)

Sogata ochrias (Kirkaldy)

Delphacodes dryope (Kirkaldy)

These are four species of delphacid leafhoppers which are abundant in low grasses of the coast, such as Bermuda grass and *Lepturus*(?). Possibly other species of delphacid leafhoppers will be found among our material when fully studied, as well as cicadellid leafhoppers which also occur on grasses.

Phytomyza spicata Malloch

This is the agromyzid leafminer discussed under corn insects as occurring on several kinds of grasses.

The following notes on pests of shade trees and ornamentals may be appropriately appended:

Hibiscus rosa-sinensis

Sylepta derogata (Fab.)

A leafroller moth which is more common on the hau.

Cosmophila flava flava (Fab.)

The moth of a green looper caterpillar, also more common on hau.

Hau (Hibiscus tiliaceus)

Sylepta derogata (Fab.) (Fig. 13)

A medium-size pale-buff moth whose caterpillars are leafrollers. The leaf is cut part way on one side of the midrib, and that portion rolled by several turns into a tube within which the caterpillar hides and feeds. Not abundant. It occurs also

in Africa and Asia, and in Malayan and Australian regions. We found it more abundant in Guam than in Samoa.

Cosmophila flava flava (Fab.)

The green hau looper is a different species than the one in Hawaii. The moth is yellowish-to-ferruginous in coloration. It has about the range of distribution as the preceding. We found it only occasionally in Samoa.

Acrocercops (an undetermined species)

A common leafminer, producing a blotch mine usually near the base of the leaf. An *Apanteles* parasite was reared from it.

Mesohomotoma hibisci (Froggatt)

This is a large green psyllid which occurs in colonies on the new foliage at tips of branches. It occurs in Australia, New Caledonia, Guam, Fiji, and Tahiti. An undetermined lacewing fly and syrphid fly larvae were found feeding on the psyllids, and an undetermined chalcid fly was reared as an internal parasite.

Chrysomelid (undetermined species)

A fairly large-size chrysomelid beetle and its larvae were found feeding in buds of terminal shoots.

Croton

Aleuroplatus samoanus Laing

This white fly was found very abundant on a croton hedge at one locality.

Erythrina

Othreis fullonia (Clerck)

This large moth has a wide range in tropical Africa, Asia and Australia, and in New Guinea, Fiji, Samoa and Guam. The moth is said to be injurious to fruit. The large black prettily marked caterpillars feed on leaves of *Erythrina.*

Argyroploce rhynchias (Meyrick)

Larvae of a large tortricid moth, which appears to be this species, were found feeding on seeds in pods of *Erythrina,* on the tree. It is related to the moth whose larvae destroy such a large proportion of koa seeds in Hawaii. It is recorded from *Canavalia* seeds in Mauritius and from Ceylon, but not previously in Samoa.

Calophyllum inophyllum

Leptynoptera sulfurea Crawford

A delicate psyllid which lives beneath the recurved margins of young leaves of this tree and causes crippled abnormal leaves. It occurs also in Guam and the Moluccas.

Terminalia catappa

Thiotricha strophiacma Meyrick (Fig. 14)

This is a minute whitish moth whose larvae feed on the surface of the leaves. Each one cuts out an oval piece of leaf about 7 mm. by 10 mm. which it uses as a shield and moves about from place to place as it feeds beneath it. There may be

2 to 20 of these per leaf. Two leaves with a maximum number had 21 and 25 holes respectively where these shields had been cut out.

Acrocercops(?) (undetermined)

A minute lepidopterous leafminer was found mining the leaves to some extent, but it was not reared.

Adoretus versutus Harold

This is the beetle discussed under corn insects. The beetles feed very extensively on *Terminalia* trees, as evidenced by the abundantly perforated leaves.

Coleus

Psara stultalis (Walker)

A pale light-brown moth with fuscous markings whose caterpillars were quite abundant as leafrollers on Coleus. This moth has a very wide distribution: India, China, Malayan region, Australia, Guam and the Marquesas. It was previously recorded from Samoa. Nothing is given of its feeding habits in the other regions, except that in Guam it was reared from an unidentified plant.

Ageratum conyzoides

Homoeosoma ephestidiella Hampson

This is a small gray phycitid moth whose larvae feed in the flower heads of *Ageratum*. It was quite common and moths were collected from the plant and also reared from the larvae. It was previously recorded from Samoa but no food plant mentioned. It is also known in India.

Spathulina acroleuca Schiner

A pretty little trypetid fly was abundant; it was swept from the plant, and reared from maggots in flower heads where growing seeds were destroyed.

Orchids (Wild Species)

The numerous species of native orchids in the forest were remarkably free from insect attack. However, a few plants were found heavily infested with an undetermined scale insect. Also a few plants were found with leaf miners and some with leafrollers but none reared.

Ferns

Pachyrhabda amianta Meyrick (Fig. 17)

A tiny white moth whose larvae feed on the spores of *Asplenium nidus,* the bird's-nest fern. The larvae feed beneath a flat round disk of webbed-together sporangia and are quite numerous, often dozens of them are seen per frond. An *Apanteles* parasite was often reared from the larvae. This moth is known only in Samoa.

Pachyrhabda antinoma Meyrick

This is another tiny moth whose larvae feed on fern spores of a particular fern (undetermined). The moth has a faint yellowish tinge. The larvae feed beneath

a slight web amongst the sporangia. This moth occurs also in India, East Australia and the Kermadec Islands.

Cossonid weevil (undescribed new species)

A small black cossonid weevil was found very numerous, both larvae and adults, in the living stems of the larger fronds of *Angiopteris evecta* var. *vaupelii* fern. Usually a large proportion of these frond stems were found infested. In case of one large plant, there were only two stems unattacked.

Cranefly (undetermined species)

A cranefly was reared from the living frond stem of an *Aspidium* (?) fern. Nearly all of the stems of this particular fern had been bored lengthwise by the elongate larvae of the cranefly. Transformation took place within the burrow.

Soil Fertility as Affected by Soil Nitrogen

By R. J. Borden

Soil fertility has been defined as "the ability of a soil to produce a crop"; the assumption is, of course, that the environment for the specific crop is satisfactory. When good crop yields have been obtained, the soil fertility has been termed "high," and conversely when the yields were subnormal we have called it "low fertility."

Successful modern agriculture has taken advantage of and applied the findings of its experienced farmers and research men to the end that soils have been made more fertile. This has entailed various modifications in the structural characteristics of the soil profile, with subsequent known adjustments of the soil's air, moisture, and nutrient supply.

In spite of our knowledge and ability to make these adjustments there are still some very elusive factors concerned with soil fertility that we have apparently not controlled. Just what these factors are, we have not definitely proved, but we have our major suspicion which will be revealed as this discussion progresses. Whether or not we can identify, measure, evaluate, and finally find some economical control for these factors is a question that only a considerable amount of new research can answer.

Technique: Our knowledge of factual differences in soil fertility comes largely from our experiences with the growing of various grass crops in pot-culture studies under controlled conditions. The plants in these comparative studies are all grown under equalized exposure, temperature, and sunlight conditions. The source of seed is the same. The same amounts (volume) of soil are used and identical fertilization supplied. Irrigation is adequate and similar, and no leachates are lost. All conditions of environment and culture, except for the variable being studied, are as near alike as we can possibly make them. That we are quite successful in providing identical conditions is shown by the fact that duplicate pots *with the same soil* produce within a given growth period amounts of total dry weight which seldom vary by as much as 10 grams in 200 grams harvested (see Table I, column headed "Duplicates"). And yet the average yields of dry matter which are harvested *from different soils* may show very significant differences, even after all of these efforts to provide identical conditions.

Seasonal Variation: It is natural to expect, and we do secure, differences in dry weight which are due to the seasonal conditions that exist during a specific cropping period. We have secured an indication of what this difference might be by planting panicum grass in pure silica sand fertilized with identical amounts of complete nutrients, at monthly intervals throughout the year, and harvesting the crop produced after its second 30 days of growth. The following yields of dry matter grown in the respective months indicated, probably represent the effects of the seasonal influences which we did not attempt to control.

PANICUM GRASS GROWN IN SILICA SAND WITH COMPLETE NUTRIENTS
AMOUNTS OF DRY MATTER PRODUCED IN DIFFERENT MONTHS

Jan.	100.6 gms.	May	136.4 gms.	Sept.	141.9 gms.
Feb.	93.9 "	June	167.9 "	Oct.	132.1 "
Mar.	100.2 "	July	153.4 "	Nov.	93.0 "
Apr.	108.6 "	Aug.	156.0 "	Dec.	80.0 "

Again, when different amounts of nitrogen were supplied to a crop of panicum grass started in June, the yields that were harvested were considerably larger than those secured from corresponding amounts of nitrogen applied to the same soil for a crop started in December.

The total amounts of nitrogen recovered in the total dry weights harvested were not widely different. Unfortunately root weights and analyses were not secured, but soil analyses after both harvests showed no available nitrogen left in the cropped soil. Apparently the difference in yields between the two series was not due to the amount of nitrogen available, but to a greatly enhanced efficiency of nitrogen during that growth season which followed the June planting.

YIELDS AND NITROGEN RECOVERED IN PANICUM GRASS GROWN ON THE SAME SOIL, BUT FROM CROPS STARTED IN DIFFERENT SEASONS (PROJECT A-105–NO. 104)

Amt. N applied	Series A—Planted in June, Harvested at 92 days: Dry wt. (gms.)	N in dry wt. (gms.)	Series C—Planted in Dec., Harvested at 94 days: Dry wt. (gms.)	N in dry wt. (gms.)
0	47	.113	53	.155
.55 grams	209	.438	159	.446
1.10 grams	282	.903	216	.970
1.65 grams	294	1.265	234	1.286
2.20 grams	329	1.646	228	1.710

Series A—R.C.M. nitrogen in soil at planting=15 p.p.m.
Series C—R.C.M. nitrogen in soil at planting=20 p.p.m.

In still another test we have cropped one of our "stock soils," at 3-month intervals, with panicum grass which had been supplied with identical treatment and growth conditions, and have obtained the following dry weights during a 90-day growth period:

Planted in	Avg. grams of dry wt. harvested: Without N	With N (1.1 gms.)
November 1938	19	169
February 1939	24	228
May 1939	31	299
August 1939	39	301

A check on the available nitrogen content of this air-dried "stock soil" during the year's storage has shown it to vary only between 24 and 32 p.p.m., and, since adequate N, P, and K fertilizers were supplied for these crops, it is felt that the results quite clearly indicate the seasonal influences.

If further evidence is desired concerning this seasonal effect upon the amount of total dry matter which can be produced with a specific and similar amount of fertilizer, then a glance at the results in Table I will show that even with slightly longer growing periods the average levels for dry matter harvested from these soils

are progressively less for Groups 1 and 2, and also for Groups 3, 4, and 5, even though identical culture has been given to and within these groups. Thus we are aware of uncontrollable seasonal influences. But when we supply different soils with *the same* growth season, *the same* geographical environment, and with optimum moisture, then fertilize them with phosphate and potash in identical amounts which are also fully adequate for maximum yields, and likewise supply uniform applications of nitrogen, then we must look for another answer to explain the differences in the yields that come from these soils.

TABLE I

YIELDS OF PANICUM GRASS GROWN WITH COMPLETE NUTRIENTS IN MITSCHERLICH POTS WITH DIFFERENT SOILS

		Soil No.	Grams dry wt. harvested: Duplicates	Avg.	S.E.*
Group 1: Planted 8/14/39, Harvested 11/8/39, Age 86 days	H. C. & S. Co. 7B	3116	215.4, 214.4	214.8	0.4
	Koloa 35	3120	245.5, 251.0	248.3	2.8
	Koloa 8	3118	251.0, 257.9	254.5	3.5
	Waianae 10	3128	267.0, 272.4	269.7	2.7
	Waiakea 13–2	3126	270.2, 275.4	272.8	2.6
	Lihue P–2M	3124	274.8, 271.8	273.3	1.5
	Kaiwiki 35	3122	276.9, 274.6	275.8	1.2
	Grove Farm 23E	3130	280.9, 272.9	276.9	4.0
	Grove Farm 12	3132	290.5, 285.2	287.9	2.7
Group 2: Planted 9/21/39, Harvested 12/28/39, Age 98 days	Kekaha 303 (3)	3170	150.6, 158.5	154.6	4.0
	Kekaha 303 (2)	3168	160.9, 151.5	156.2	4.7
	Wailuku 19	3166	197.7, 197.7	197.7	0
	Maui Ag. 22	3160	202.3, 201.5	201.9	0.4
	Lihue 28 Hm	3162	212.3, 205.2	208.8	3.6
	Hutchinson 31	3164	232.0, 233.7	232.9	0.9
Group 3: Planted 8/30/39, Harvested 11/22/39, Age 84 days	Waialua Gay 2	3134	231.0, 237.7	234.4	3.4
	Kemoo 9	3144	240.6, 240.1	240.4	0.3
	Gay 9	3136	243.8, 244.9	244.6	0.6
	Kawailoa 6	3141	283.2, 284.6	283.9	0.7
	Helemano 7B	3139	289.5, 289.3	289.4	0.1
	Kawaihapai 6	3140	302.7, 299.3	301.0	1.7

TABLE I—Continued

YIELDS OF PANICUM GRASS GROWN WITH COMPLETE NUTRIENTS IN MITSCHERLICH POTS WITH DIFFERENT SOILS

			Soil No.	Grams dry wt. harvested: Duplicates	Avg.	S.E.*
Group 4	Planted 9/28/39, Harvested 12/28/39, Age 91 days	Waialua Gay 3	3172	203.5, 203.5	203.5	0
		Gay 3A	3174	210.4, 211.5	211.0	0.6
		Gay 8A	3175	214.0, 215.8	214.9	0.9
		Kawaihapai 18	3180	230.4, 222.4	226.4	4.0
		Kawaihapai 13	3179	235.5, 234.6	235.1	0.5
Group 5	Planted 10/19/39, Harvested 1/26/40, Age 99 days	Waialua Gay 3	3193	165.4, 165.9	165.7	0.3
		Kawailoa 14A.	3197	184.6, 186.5	185.6	1.0
		Kawaihapai 2B	3199	188.4, 186.0	187.2	1.2
		Kawaihapai 4.	3201	200.3, 207.1	203.7	3.4
		K'wpai 2B2...	3200	211.5, 206.7	209.2	2.4

*Standard error.

Variation in Grass Yields: In Table I, we show data for 5 groups of soils which are a typical cross section of several hundred similar groups that we have studied in connection with our Mitscherlich soil testing. Within each group the results should be strictly comparable, for the panicum grass crops have had the same growth season and identical treatments.

(a) In Group 1, nine soils gathered from widely scattered locations throughout the Islands show significant differences in their fertility when cropped under an identical environment. They have had an adequate supply of water, phosphate, and potash for a maximum crop, and it is not believed that any so-called "minor element" deficiency has existed, although we do not mean to disregard this possibility. Satisfactory conditions for drainage and soil aeration have prevailed. Nitrogen fertilizer has been supplied to all soils alike but not necessarily in an amount sufficient to produce the maximum yield in each soil; hence if the soil itself has been able to supply additional nitrogen from its own natural store, such nitrogen would be a contributing factor to these increased yields. This is just what we believe has happened.

(b) In Group 2, these six very different soils have also produced widely different yields from identically applied treatments. It may be of interest to note that soils Nos. 3170 and 3168 are from virgin cane areas; presumably they have not been able to supply much additional nitrogen from their natural supply.

(*c*) Groups 3, 4, and 5 are all made up from soils taken within a single plantation. They show almost as much differentiation in their ability to produce panicum grass crops under identical conditions as do the soils from the more widely scattered locations represented in Groups 1 and 2.

If still further evidence is needed to support our belief that it is the soil nitrogen supply which dominates this soil fertility picture, then we might present the yields secured from 22 different soils, identically treated and cropped, both (*a*) without added nitrogen fertilizer, and (*b*) with identical amounts of nitrogen. Since phosphate and potash were supplied to all soils alike, in amounts sufficient for maximum yields, the results are apparently the effects of the ability of these different soils to supply nitrogen for their crops (Project A-105—No. 48.017). There is a positive correlation both (*a*) between the yields "with nitrogen" and the yields "without nitrogen" ($r = + .71 \mp .11$), and (*b*) also between the yields "with nitrogen" and the "% available N by R.C.M." ($r = .56 \mp .15$).

TABLE II

GRAMS DRY WEIGHT HARVESTED
(AVERAGES OF 4 POTS)

Pot nos.	Source	Without nitrogen	With 1 gm. nitrogen	% increase for nitrogen	% available N by R.C.M.
1340–43	Waianae	27	328	1,128	.0015
1540–43	Waimanalo	47	356	660	.0040
1536–39	Waialua	50	362	620	.0018
1412–15	Makiki	65	348	438	.0078
1368–71	Puhi	67	352	425	.0030
1348–51	Kahuku	89	378	326	.0035
1388–91	Ookala	104	372	257	.0073
1344–47	Kahuku	127	375	195	.0065
1372–75	Puhi	127	369	190	.0093
1360–63	Puhi	131	378	190	.0088
1352–55	Kahuku	136	387	184	.0088
1380–83	Hamakua	139	386	177	.0060
1376–79	Puhi	139	385	176	.0100
1384–87	Ookala	143	309	116	.0050
1364–67	Puhi	148	396	167	.0090
1404–07	Naalehu	157	390	148	.0118
1396–99	Naalehu	158	387	145	.0060
1392–95	Ookala	176	372	111	.0118
1544–47	Hana	187	416	122	.0070
1408–11	Naalehu	202	406	100	.0128
1356–59	Koloa	215	404	88	.0163
1400–03	Naalehu	223	409	84	.0075

Effects on Sugar Cane: To the sugar man, this discussion will become more pertinent if we can show similar effects on cane from similar inherent differences in soil fertility. Our data are not as extensive and experimental errors are somewhat larger, but nevertheless they are quite convincing.

In Table III, we have the total dry weights of H 109 cane harvested at 12 months from 23 different soils which were cropped under an identical environment and given identical fertilization.

In Table IV, we give the yields of 31–1389 and of D 1135 from 12 different soils which were also identically cropped.

TABLE III

TOTAL DRY WEIGHTS OF H 109 CANE HARVESTED AT 12 MONTHS, AND GROWN WITH IDENTICAL TREATMENT AND ENVIRONMENT ON 23 SOILS (AVERAGES OF 3 POTS)

Identity	Soil No.	Total dry wt. (gms.)	Identity	Soil No.	Total dry wt. (gms.)
Kauai Var. Sta.	25*	653	Ewa—B	15	1,111
Libby—134	19*	678	Kohala—7A	45*	1,128
Manoa—37	1	903	Hamakua—27K	33	1,136
Ewa—19D	17	911	Onomea—64	41	1,139
Hawn. S.—A1-D	27	962	Grove Farm—31C	21	1,186
Hamakua—32K	35	981	Kailua—B	5	1,198
Ham. Var. Sta.	31	991	Kahuku—4 (g)	11	1,274
Kilauea—28D	23*	1,002	Pepeekeo—38	43	1,282
Waipio—Yamada	7*	1,067	Hawn. Agr.—H 23	39	1,331
Ewa—19A	13*	1,073	Kahuku—4 (p)	9	1,335
H. C. & S.—8	29	1,084	Hawn. Agr.—M2-1	37	1,450
Kailua—K	3	1,086			

Difference needed for significance: for odds of 99 to 1 = 172 grams.

*These 6 soils have probably responded to applications of minor elements but, even so, the resultant yields within this group are widely different and indicate some more dominant factor as the cause thereof.

Soil No.	Average dry weights (gms.) Without additional "minor elements"	With additional "minor elements"
25	653	765
19	678	785
23	1,002	1,158
7	1,067	1,118
13	1,073	1,143
45	1,128	1,253

TABLE IV

TOTAL DRY WEIGHTS OF 2 CANE VARIETIES* HARVESTED AT 12 MONTHS AND GROWN WITH IDENTICAL TREATMENT AND ENVIRONMENT ON 12 DIFFERENT SOILS (AVERAGES OF 4 POTS)

Source of soil	Soil No.	31–1389 Dry weight (gms.)	D 1135 Dry weight (gms.)
Kihei	H7	850	608
Hakalau	H2	877	1,005
Haleakala	M6	919	760
Kahuku	K12	985	765
Mountain View	O3	1,040	1,019
Helemano	H8	1,122	808
Makiki	M10	1,122	1,051
Makaweli	H4	1,174	1,076
Kapapala	H1	1,177	1,090
Moanalua	H11	1,193	1,082
Waianae	W9	1,252	1,018
Kilauea	K5	1,275	906

Difference needed for significance: for odds of 99 to 1 = 145 grams.

*An analysis of variance suggests a significant interaction between the varieties and the soils; this fact will further complicate our efforts to identify the dominating fertility factors. Thus soils H2 and K5, especially, show widely different effects on the two varieties of cane.

Thus there is real evidence that different soils will also produce differences in cane yields which cannot be explained on the basis of differences in sunlight, temperature, exposure, or of inadequacies in soil moisture or air, or in fertilization with the N, P, and K of commercial fertilizers.

We have already indicated that we suspect that soil nitrogen is the principal factor responsible for the yield differences we have cited. This idea is not new or original but it is apparently one that we have chosen to pay little attention to, for our research has yet to answer many questions that are suggested when we try to list the factors which might affect the supply of available soil nitrogen during the long growing period of a sugar cane crop.

We do not need to discuss herein the need for and the effects of nitrogen fertilization for sugar cane. We know how to recognize nitrogen deficiency and how to correct it, and it is doubtful if we are actually growing any of our cane crops today with an insufficient supply of nitrogen. What we are more concerned with is the avoidance of an excess of nitrogen, because of its detrimental effects on cane quality and the unsound economics it involves. Just one of the results from our controlled skirmish tests will be drawn upon to illustrate this (A-105—No. 126: Treatments Nos. 5 and 6):

AVERAGE YIELD DATA AND ANALYSES SECURED WHEN INADEQUATE, OPTIMUM OR EXCESSIVE NITROGEN WAS FURNISHED TO 31–1389 CANE HARVESTED AT 12 MONTHS (AVERAGES OF 8 POTS)

Nitrogen applied	Grams per pot	Total dry wt. (gms.)	Lbs. cane	Y % C	Lbs. sugar	% N in juice	% N in leaves*
Inadequate	3	851	3.69	13.48	.48	.012	.94
Optimum	6	1,187	5.21	13.33	.70	.028	1.40
Excessive	9	1,144	4.70	11.41	.54	.067	1.80
Difference needed for significance:							
Odds of 99 to 1......		65	.59	.84	.07	.018	....

*Single sample only.

Thus the use of an excessive amount of nitrogen is clearly shown to be uneconomic.

Many Problems: If we are to use nitrogen fertilizer intelligently we have much to learn. For instance, these questions suggest themselves:

1. What part of the total soil nitrogen supply can be made available? (*a*) When? (*b*) How?

2. Is there a continued replenishment of the available nitrogen supply from this total nitrogen of the soil profile? (*a*) At what rate? (*b*) In what amount?

3. What part of the nitrogen fertilizer that is taken up by the weeds, the soil organisms, and the trash of a current cane crop will be returned and made available for subsequent uptake by this same crop? (*a*) How long will this take? (*b*) Can we speed up the procedure?

4. Is the nitrogen content of the stubble and of the old root system a source of supply for the subsequent crop?

5. What relation exists between the cane tonnage harvested, the root mass and stubble it leaves behind in the soil to decay, and the efficiency of subsequent nitrogen fertilization?

6. How may differences in field practices, which result in different amounts of unburned trash being left on a ratoon field, influence the results from a specific nitrogen application?

7. Can the available nitrogen supply in the soil of ~~a field~~ that is being cropped continually with sugar cane be "built-up" ~~by~~ nitrogen fertilization in the same manner that the soil phosphate supply can be permanently increased?

Perhaps one major question is all that is needed to suggest these same problems, *i.e.*, "How does the soil organic matter affect the results which are expected when we fertilize sugar cane soils with nitrogen?" for it is at once apparent that all of these questions suggest a relationship between nitrogen and the soil organic matter, and that the answers are those which will come largely from the researches of the soil biologist, for we believe that it is the number, nature, and seasonal activities of the soil microorganisms under the constantly changing conditions which we artificially create through our various cultural and fertilizer and irrigation practices, that hold the key to the correct answers.

Unfortunately we have made few studies of this biological activity in our soil fertility research. But we do have considerable evidence, that has been obtained by measuring the effects from known additions of nitrogen and organic materials to soils, that in itself suggests the influence of soil microorganisms, and indicate how difficult it is to predict expected results from a specific nitrogen fertilizer application without knowledge of the expected response from the soil population.

An accompanying photograph (Fig. 1) from Project A-105—No. 136 shows at 8 and at 16 weeks comparative growth of 31–1389 cane on 5 soils, which when potted had the following amounts of available nitrogen: left to right 8, 39, 63, 82, and 101 p.p.m. No additional nitrogen fertilizer has been supplied, and there is an excellent agreement between the original content of available soil nitrogen and the yields.

We noted somewhat similar evidence while studying the relation between panicum grass yields and available soil N in Table II.

However, our final agreement is not always as good as this. We can show some weaknesses in this agreement for the results in Tables I, III, and IV. For example, when we arrange the average dry weights harvested from the "complete fertilizer" series in an ascending order of values and set against these values certain other measurements, we can by inspection alone see the absence of a good correlation with the available (?) nitrogen supply, as measured by our R.C.M. and Mitscherlich tools (see Table V). Apparently our designation of "available" nitrogen is somewhat incomplete and in some instances it may be of questionable use in enabling us to determine the amount of nitrogen which the cane crop can be expected to pick up during its long growth period.

Fig. 1

Comparative growth of 31–1389 cane on 5 different soils. Upper: at 8 weeks; lower: at 16 weeks.

Soil	p.p.m. N at potting	Grams dry weight produced at 8 weeks	Grams dry weight produced at 16 weeks
L	8	15.6	21.4
ML	39	25.2	40.3
M	63	28.7	63.4
MH	82	34.2	84.6
H	101	33.9	99.6

TABLE V

SOME RELATIONS BETWEEN YIELDS AND AVAILABLE NITROGEN IN SOIL AT PLANTING, WITHIN EACH OF 5 GROUPS OF SOILS

(*a*) Data associated with panicum grass yields from Table I.

	No.	Avg. dry wt. with complete fertilizer	Avg. dry wt. without N	Nitrogen in soil at planting p.p.m. by R.C.M.	Nitrogen in soil at planting lbs. per acre by Mitscherlich test
Group 1	3116	214.8	32.0	40	73
	3120	248.3	78.6	43	175
	3118	254.5	40.0	28	81
	3128	269.7	55.3	96	119
	3126	272.8	165.6	85	200
	3124	273.3	74.3	36	149
	3122	275.8	53.1	38	97
	3130	276.9	44.7	63	84
	3132	287.9	75.0	68	141
Group 2	3170	154.6	40.6	28	138
	3168	156.2	39.0	35	129
	3166	197.7	63.9	35	193
	3160	201.9	47.2	61	128
	3162	208.8	58.6	63	162
	3164	232.9	50.5	80	131
Group 3	3134	234.4	38.5	28	85
	3144	240.4	53.8	73	120
	3136	244.6	38.1	26	78
	3141	283.9	45.3	26	92
	3139	289.4	53.6	33	98
	3140	301.0	47.2	28	74
Group 4	3172	203.5	35.5	15	86
	3174	211.0	43.0	25	110
	3175	214.9	46.2	33	116
	3180	226.4	47.7	38	102
	3179	235.1	45.9	35	93
Group 5	3193	165.7	19.0	23	57
	3197	185.6	32.3	45	94
	3199	187.2	22.3	23	58
	3201	203.7	35.6	30	93
	3200	209.2	34.6	28	84

TABLE V—Continued

SOME RELATIONS BETWEEN YIELDS AND AVAILABLE NITROGEN IN SOIL AT PLANTING, WITHIN EACH OF 5 GROUPS OF SOILS

(*b*) Data associated with cane yields from Tables III and IV.

Cane var.	Soil No.	Dry weight harvested (gms.)	p.p.m. available N by R.C.M.	Cane var.	Soil No.	Dry weight harvested (gms.)	p.p.m. available N by R.C.M.
H 109	25	653	8	31–1389	H7	850	53
	19	678	16		H2	877	12
	1	903	8		M6	919	18
	17	911	8		K12	985	9
	27	962	16		O3	1,040	17
	35	981	16		H8	1,122	63
	31	991	15		M10	1,122	18
	23	1,002	14		H4	1,174	11
	7	1,067	20		H1	1,177	25
	13	1,073	14		H11	1,193	13
	29	1,084	7		W9	1,252	6
	3	1,086	8		K5	1,275	115
	15	1,111	16				
	45	1,128	24	D 1135	H7	608	53
	33	1,136	20		M6	760	18
	41	1,139	28		K12	765	9
	21	1,186	43		H8	808	63
	5	1,198	16		K5	906	115
	11	1,274	23		H2	1,005	12
	43	1,282	37		W9	1,018	6
	39	1,331	18		O3	1,019	17
	9	1,335	50		M10	1,051	18
	37	1,450	26		H4	1,076	11
					H11	1,082	13
					H1	1,090	25

The Search for Facts: With such a background of information, the premise we held was to the effect that the soil microorganisms were in control of soil nitrogen availability. Being without the necessary experience and equipment to measure this microorganic content and its activity directly, we proposed a skirmish test (Project A-105—No. 46.4) that we hoped would measure its effects by securing frequent samples for analyses of the available (R.C.M.) nitrogen content of uncropped soils to which varying amounts of nitrogen fertilizer and organic matter were to be added, and which were to be given optimum conditions to encourage the maximum activity of the desirable soil organisms.

Two soils which we have previously studied quite extensively were selected. These may be briefly described as follows:

Characteristics	Manoa soil	Makiki soil
Elevation	550 ft.	40 ft.
Origin	Residual	Alluvium
Color	Yellow brown	Dull gray brown
Texture	Light clay loam	Silty clay loam
Structure	Crumb	Nut
Consistence	Loose and friable	Plastic and sticky
Volume weight	.85	1.05
Phosphate fixation index	90	35
pH	5.4	7.2
% available N	.0024	.0015
% available P_2O_5	.014	.032 +
% available K_2O	.003 —	.018
% available CaO	.009 —	.62

We supplied adequate phosphate and potash to both soils at time of potting. Commercial nitrogen fertilizer was used at the rates of 300 and 600 pounds of N per acre (surface area). Filter cake at rates of 33 and 66 tons (wet basis) per acre provided a readily decomposable source of organic matter, and at these rates furnished equivalent amounts of nitrogen (300 and 600 pounds respectively) as were used in the commercial fertilizer.

The two soils were air-dried, screened, and thoroughly mixed before being placed in standard Mitscherlich pots. After potting, all containers were placed on flat cars which could be run into a covered greenhouse at night and during periods of rainy weather. During the 70 consecutive weeks which our analyses covered, all pots were kept moist, were protected from loss of nutrients through leaching, and were similarly exposed to direct sunlight except when greenhouse protection was necessary. Periodically, once or twice a month, the soil of every pot was removed, remixed, and returned; this should have provided adequate aeration. Hence with such conditions of moisture, temperature, and aeration, we should have had very satisfactory microorganic activity in these two soils.

The total number of pots with each soil was thereafter divided to provide for 8 treatments in each of 4 series. These treatments were as follows:

	Additions of—	
No.	Filter cake	Fertilizer nitrogen
1	None	None
2	At 33 tons/acre	None
3	At 66 tons/acre	None
4	At 33 tons/acre	At 300 lbs./acre from ammonium nitrate
4a	At 33 tons/acre	At 300 lbs./acre from ammonium sulphate
4b	At 33 tons/acre	At 300 lbs./acre from nitrate of soda
5	None	At 600 lbs./acre from ammonium nitrate
6	None	At 300 lbs./acre from ammonium nitrate

These additions were not mixed into the soils in their respective containers until the specific dates which were scheduled for the starting of each of the 4 series; this was done so that different seasonal effects might exert their influences. Thus the 4 series were started as follows: Series I in August, Series II in October, Series III in February, and Series IV in April.

From each treatment in each series a soil sample was taken after the series was started, and thereafter at intervals of 2 weeks an additional soil sample was taken. The samples were generally analyzed* for their available ammoniacal and nitrate

*Full credit for R.C.M. nitrogen analyses is acknowledged to H. M. Lee, and for sampling and general conduct of test to A. Y. Ching.

nitrogen content within a week from the time they were taken. Consecutive samples were taken during an elapsed period of 70 weeks for each series.

TABLE VI

TREATMENT NO. 1—CONTROLS (NO SUPPLEMENTS OF FILTER CAKE OR NITROGEN FERTILIZER); P.P.M. AVAILABLE NITROGEN IN SOIL SAMPLES TAKEN AT 2-WEEK INTERVALS

	Manoa soil				Makiki soil			
Month	Ser. I	Ser. II	Ser. III	Ser. IV	Ser. I	Ser. II	Ser. III	Ser. IV
1937—Aug.	24	(24)	(24)	(24)	15	(15)	(15)	(15)
Aug.	48	*	*	*	12	*	*	*
Aug.	33	*	*	*	13	*	*	*
Sept.	44	*	*	*	20	*	*	*
Sept.	45	*	*	*	15	*	*	*
Oct.	30	*	*	*	18	*	*	*
Oct.	45	42	*	*	27	17	*	*
Nov.	45	50	*	*	20	17	*	*
Nov.	50	32	*	*	28	17	*	*
Dec.	60	60	*	*	40	32	*	*
Dec.	45	45	*	*	25	16	*	*
1938—Jan.	60	45	*	*	60	25	*	*
Jan.	60	47	*	*	20	30	*	*
Jan.	..	..	*	*	..	..	*	*
Feb.	70	60	50	*	22	42	22	*
Feb.	80	75	55	*	35	40	30	*
Mar.	70	60	50	*	40	40	35	*
Mar.	75	70	70	*	50	45	50	*
Apr.	75	75	70	*	50	40	55	*
Apr.	90	75	75	70	42	40	18	30
May	102	90	90	80	42	30	40	40
May	100	100	100	80	35	40	45	30
June	120	120	100	90	45	45	45	43
June	140	130	125	100	50	50	50	50
July	150	120	120	100	35	30	40	45
July	126	126	100	100	30	40	45	40
July	130	140	132	130	35	45	50	50
Aug.	124	153	134	100	35	50	45	50
Aug.	136	143	154	134	45	55	50	50
Sept.	126	142	152	154	40	45	45	45
Sept.	126	146	154	144	45	50	45	40
Oct.	112	116	129	103	45	50	45	55
Oct.	130	140	130	132	50	50	50	50
Nov.	152	158	156	156	50	45	52	50
Nov.	128	156	142	133	45	50	58	50
Dec.	134	138	146	126	50	50	53	45
Dec.		164	164	152		56	49	56
Dec.		156	156	136		42	52	50
1939—Jan.		168	135	126		65	68	63
Jan.		162	157	136		73	72	68
Feb.		128	123	102		27	52	60
Feb.		123	145	118		19	23	52

TABLE VI—Continued

TREATMENT NO. 1—CONTROLS (NO SUPPLEMENTS OF FILTER CAKE OR NITROGEN FERTILIZER); P.P.M. AVAILABLE NITROGEN IN SOIL SAMPLES TAKEN AT 2-WEEK INTERVALS

	Manoa soil				Makiki soil			
Month	Ser. I	Ser. II	Ser. III	Ser. IV	Ser. I	Ser. II	Ser. III	Ser. IV
Mar.			154	130			52	62
Mar.			156	148			57	52
Apr.			148	106			30	54
Apr.			160	158			55	57
May			129	94			35	55
May			128	140			35	50
June			138	106			30	60
June			132	132			32	59
			—				—	
July				128				58
July				116				52
July				110				48
Aug.				101				58
Aug.				98				64
				—				—

*Not actually sampled but given the same attention and conditions, and hence were duplicates of Series I.

In Table VI we have recorded the available nitrogen content as it was found from the analyses made on consecutive samples taken from both of the "control" soils, *i.e.,* the untreated soils or Treatment No. 1, in each series. These data show a very definite increase in the available nitrogen supply which resulted when these soils, without supplements of anything other than air, water, and sunlight, were given good conditions for microorganic activity. Of special interest is the evidence of the variation in the available nitrogen content, for although the trend is certainly one which shows that an increased nitrogen content follows an increase in time from date of potting field soils, yet the consecutive samplings from the same pots of soil (*i.e.,* within any one series) sometimes show some rather surprisingly abrupt increases or decreases. We do not feel warranted in attributing any great amount of this difference to the sampling or analytical errors, but believe it to be an actual fluctuation that was controlled by the soil organisms. We believe that the rather small range in the variation of this relatively elusive available nitrogen between the four duplicates of each soil, at any single sampling period between April and November 1938, indicates considerable uniformity in the microorganic activity at any one period of time. We have considerable confidence that the sampling and analytical techniques were quite satisfactory. As a check on these techniques, we have the results of many analyses that have been made from duplicate, uncropped pots of different soil treatments taken from other studies, and these show rather close agreements between the duplicates. Here are just a few typical examples of the close agreement between duplicate pots (*"a"* and *"b"*), and the differences between such duplicates probably indicates the extent of the sampling and analytical errors in our present study:

No.	% NH_3 nitrogen	% NO_3 nitrogen	p.p.m. available nitrogen	No.	% NH_3 nitrogen	% NO_3 nitrogen	p.p.m. available nitrogen
1*a*	.0042	.0050	92	6*a*	.0005	.0027	32
b	.0042	.0045	87	*b*	.0003	.0020	23
2*a*	.0035	.0060	95	7*a*	.0002	.0045	47
b	.0040	.0050	90	*b*	.0002	.0055	57
3*a*	.0003	.0175	178	8*a*	.0003	.0024	27
b	.0003	.0160	163	*b*	.0002	.0030	32
4*a*	.0040	.0070	110	9*a*	.0002	.0045	47
b	.0040	.0080	120	*b*	.0002	.0025	27
5*a*	.0060	.0080	140	10*a*	.0010	.0022	32
b	.0055	.0080	135	*b*	.0010	.0022	32

The analytical data are voluminous and hence need simple graphical presentation for clear comprehension. Variations in the amounts of available nitrogen which were found in consecutive samples have made it advisable to present the data on a basis of running averages for 3 consecutive analyses rather than to attempt to plot the analyses of single samples. (One exception is presented in Figs. 8 and 9 which are purposely introduced for comparison with Figs. 6 and 7.) Finally, figures for ammoniacal and nitrate nitrogen have been combined and are presented as total p.p.m. available nitrogen, except in Fig. 17 where the progress of nitrification of ammonium sulphate is shown.

We turn then to a study of the graphs.

Figs. 2 and 3: Series I was started in August. The difference in the available nitrogen levels of the two soils without additional nitrogen fertilizer or filter cake (Treatment No. 1) is striking. Although this difference was not very great at the time the two soils were potted, it became increasingly greater with time. In April when the Makiki soil had reached its peak amount, the available nitrogen in the Manoa soil was still increasing, and in July this Manoa soil had increased its available nitrogen by well over 100 p.p.m. more than it started with.

When nitrogen fertilizer was supplied without filter cake (Treatment No. 6) the effect on the available nitrogen of the two soils was quite dissimilar. On the Manoa soil, there was an immediate and definite increase during a period of 8 weeks in August and September followed by a corresponding drop through October, November and December, and then a sharp rise which continued and reached a peak in midsummer; thereafter in September and October it again fell off. On the Makiki soil the corresponding treatment (No. 6) immediately showed a drop in its nitrogen content which continued through November and then started to rise, reaching its peak with considerably more irregularity than the Manoa soil at about the same time in midsummer, thereafter dropping off both a little faster and a little sharper. Whereas the Manoa soil apparently had a greater available N content at the end than at the start of this study, the Makiki soil had quite definitely locked up or lost some of the soluble nitrogen fertilizer which it had received.

With the increase in soil organic matter which resulted when filter cake was added to these soils, we note an immediate drop in the available nitrogen content. For a few weeks after this material was incorporated with the soil the total available nitrogen content was almost nil when no nitrogen fertilizer had been supplied (Treatment No. 2) but thereafter it began to "come back." After approximately 30 weeks on the Manoa soil, it caught up with and then produced more nitrogen than

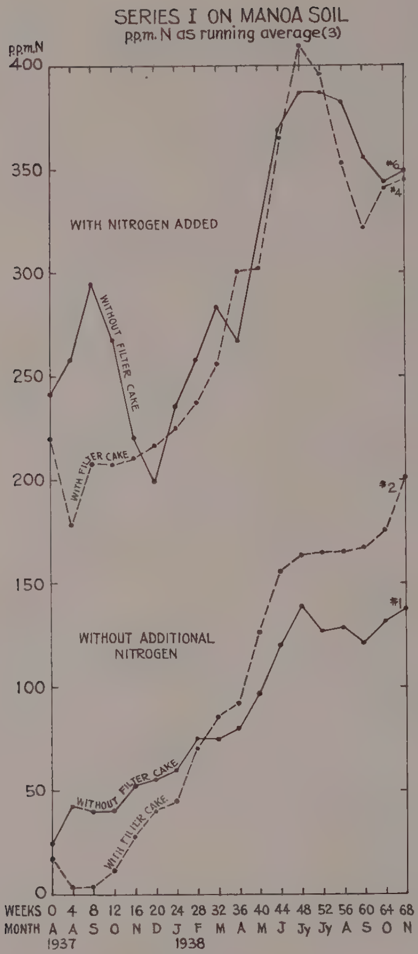


Fig. 2

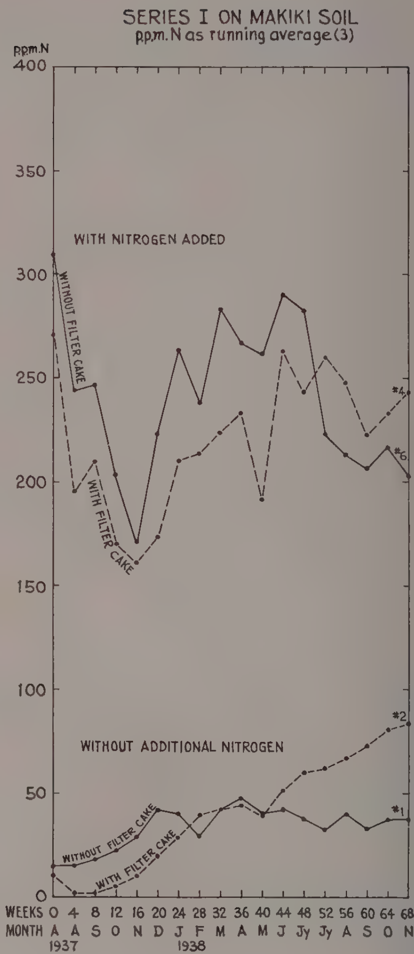


Fig. 3

the corresponding soil which had not had the filter cake. On the Makiki soil, a similar action occurred but it was somewhat slower and some 40 weeks had elapsed before it had produced more nitrogen than its control. At the end of 70 weeks both soils had recovered about the same amounts of nitrogen from that supplied as a constituent of their respective filter cake additions.

When nitrogen fertilizer was also supplied with the filter cake (Treatment No. 4), the issue is not as clear as when no extra nitrogen was given. On the Manoa soil it is doubtful if the nitrogen content of the filter cake contributed anything to the available supply; on the Makiki soil it most certainly did not do so for a whole year, and the indication of a small increase thereafter is perhaps not highly significant. Hence it would appear that when this filter cake was used with the additional nitrogen fertilizer, it contributed very little available nitrogen to these soils within a period of 70 weeks.

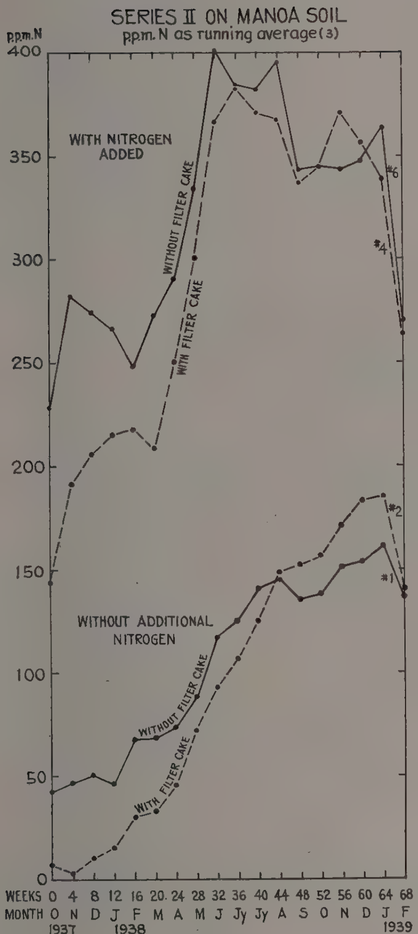


Fig. 4

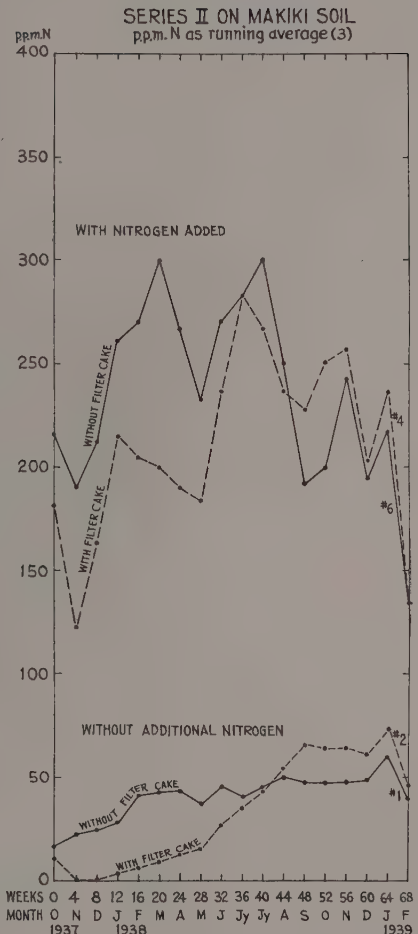


Fig. 5

Figs. 4 and 5: Series II was started in October. The picture shown in Figs. 4 and 5 is not entirely unlike that in Figs. 2 and 3 which we have just discussed. We note the same higher level of available nitrogen in the Manoa soil and its steady increase during the warm summer months, which is again in contrast to the relatively constant supply of nitrogen in the Makiki soil during this same time. We also note the immediate rise, fall, rise, and fall of Treatment No. 6 on the Manoa soil, and the corresponding immediate drop, rise, and gradual falling off again of the nitrogen in the Makiki soil without filter cake.

We find the same rapid depression in the available nitrogen content that follows the addition of the filter cake in both soils, but in this Series II, the nitrogen that is tied up by the filter cake in the Manoa soil is apparently not released until nearly a year later, and thereafter does not contribute as definitely to the total available supply as it did in Series I. Likewise on the Makiki soil the filter cake has apparently not contributed some of its nitrogen as definitely as it did in Series I on this same soil.

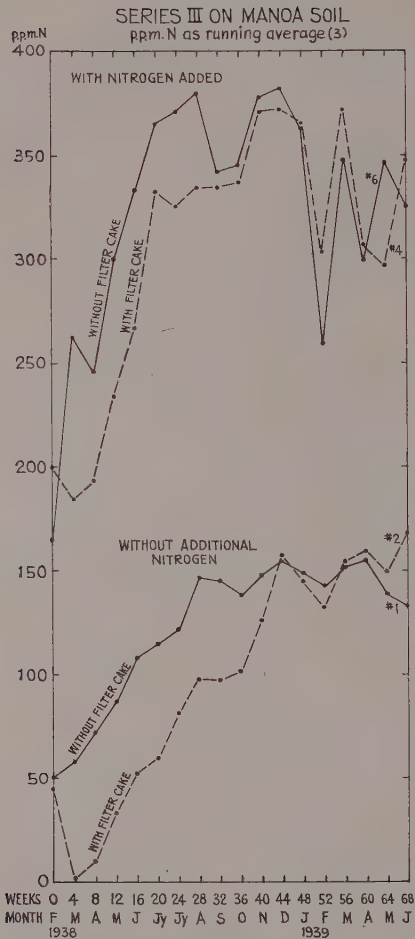


Fig. 6

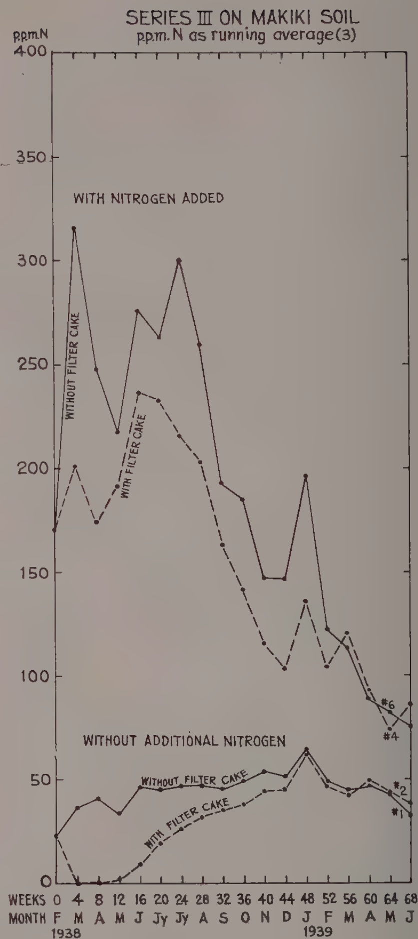
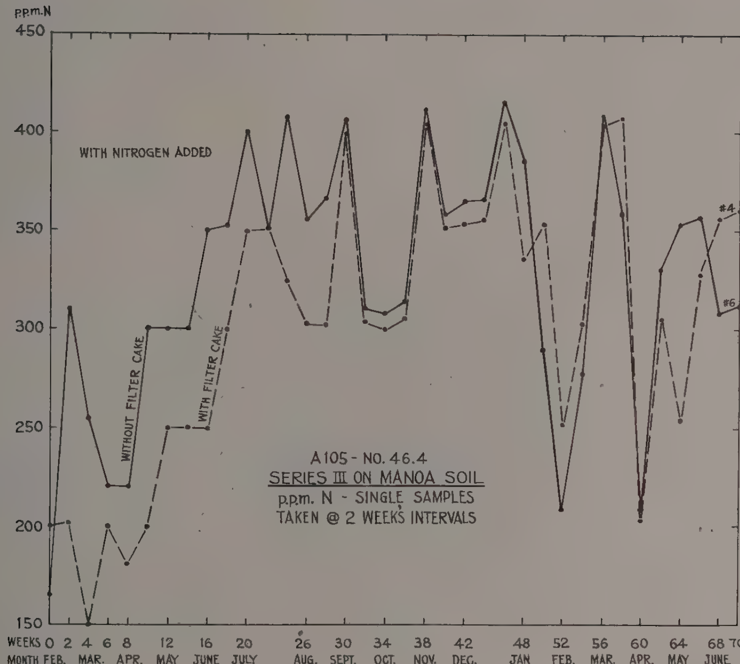


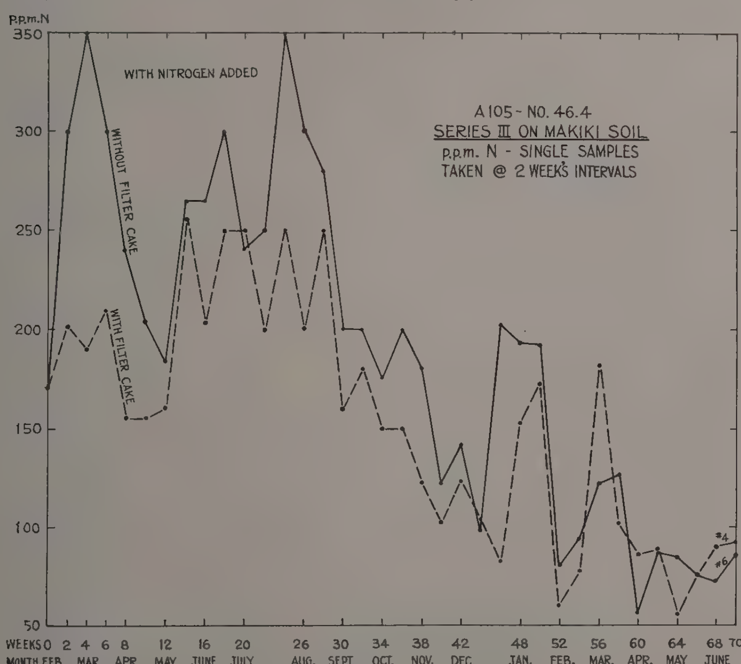
Fig. 7

Used with nitrogen fertilizer, the filter cake additions to both soils show negligible, if any, contribution to the total available nitrogen supplies therein.

Figs. 6 and 7: Series III was started in February. The graphs in Fig. 6 are quite similar to those in Fig. 4, and those for Treatments 1 and 2 in Fig. 7 are not unlike the corresponding ones in Fig. 5. The results would indicate that during the 70-week testing period, the available nitrogen levels have been reduced where this kind of organic material was added and, that even at the end of this period, there has been no real increase from the 300 pounds per acre application of the nitrogen from the filter cake.

In one respect, the graphs for Treatments 4 and 6 in Fig. 7 are quite different from their counterparts in Figs. 3 or 5; *i.e.,* the distinct and continuous loss of available nitrogen when nitrogen fertilizer was added to this Makiki soil both with and without filter cake. We are completely at a loss to explain this occurrence; we have been unable to find any errors or changes in cultural conditions, or in our


P.P.m.N
450
400
350
300
250
200
150
WITH NITROGEN ADDED
WITHOUT FILTER CAKE
WITH FILTER CAKE
#4
#6
A105 - NO. 46.4
SERIES III ON MANOA SOIL
p.p.m. N - SINGLE SAMPLES
TAKEN @ 2 WEEKS INTERVALS
WEEKS 0 2 4 6 8 12 16 20 26 30 34 38 42 48 52 56 60 64 68 70
MONTH FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN FEB. MAR. APR. MAY JUNE


P.P.m.N
350
300
250
200
150
100
50
WITH NITROGEN ADDED
WITHOUT FILTER CAKE
WITH FILTER CAKE
#4
#6
A105 - NO. 46.4
SERIES III ON MAKIKI SOIL
p.p.m. N - SINGLE SAMPLES
TAKEN @ 2 WEEKS INTERVALS
WEEKS 0 2 4 6 8 12 16 20 26 30 34 38 42 48 52 56 60 64 68 70
MONTH FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE

Figs. 8 and 9

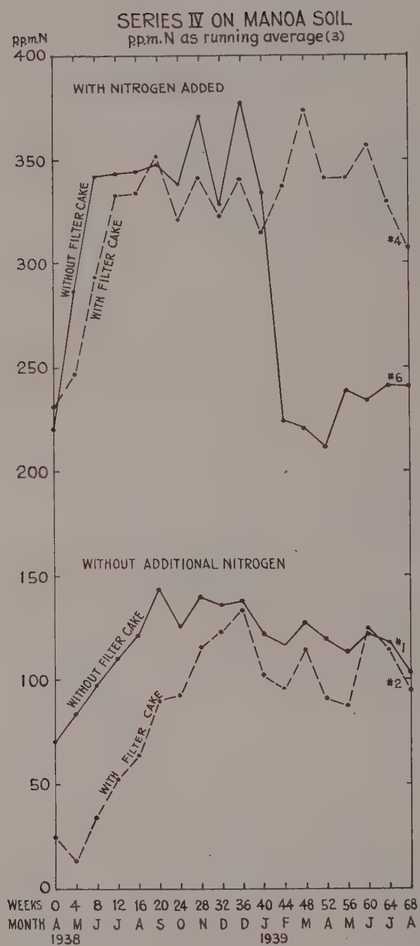


Fig. 10

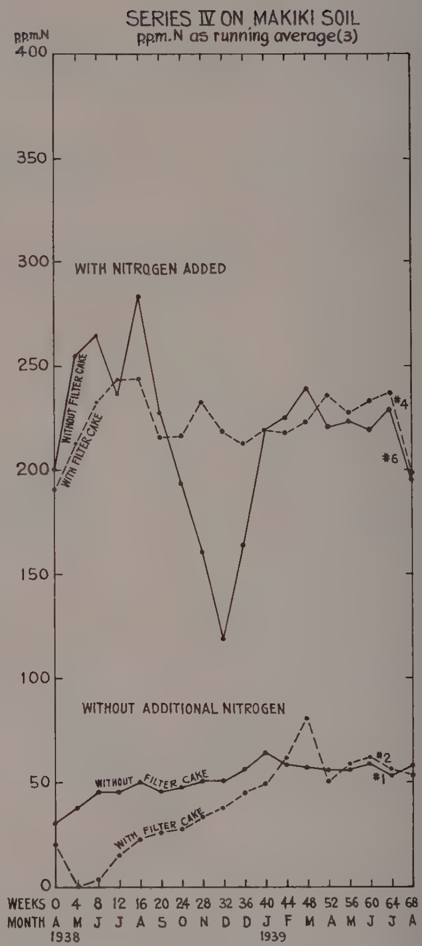


Fig. 11

sampling or analytical techniques that would indicate the data to be other than an accurate measurement of the available nitrogen that was actually present in this soil when it was sampled.

Figs. 8 and 9: Series III. These two graphs are made up from the separate analyses of the single samples taken at 2-week intervals from Treatments 4 and 6 on both soils in Series III. The same data are presented for 4-week intervals as running averages of 3 consecutive samplings in Figs. 6 and 7 and so have already been discussed.

Figs. 10 and 11: Series IV started in April. The graphs in Figs. 10 and 11 lend further support to what has already been so aptly shown, *i.e.*, (*a*) the depressing effect from applications of filter cake upon the available nitrogen supply of both soils; (*b*) the very small contribution which the nitrogen content of the filter cake actually makes to the soil supply within 70 weeks; (*c*) the unexplainable variations in the available nitrogen supply of soils, especially when nitrogen fertilizer has been added; and (*d*) the differences in the ultimate levels of available nitrogen and of the rates of increase in different soils.

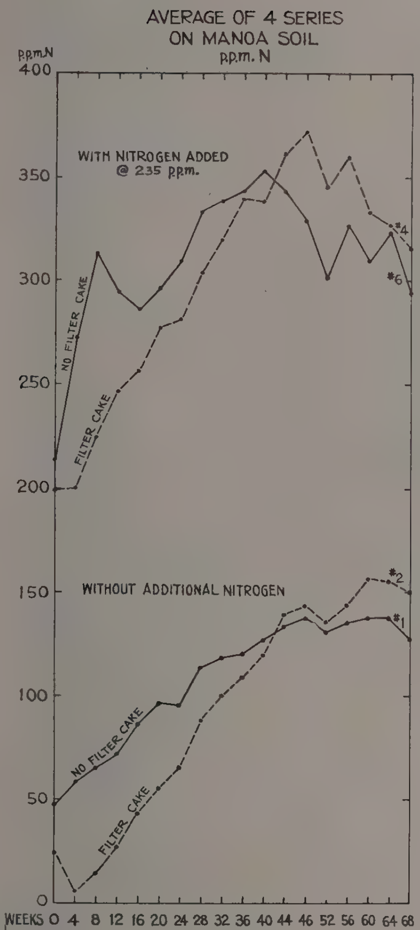


Fig. 12

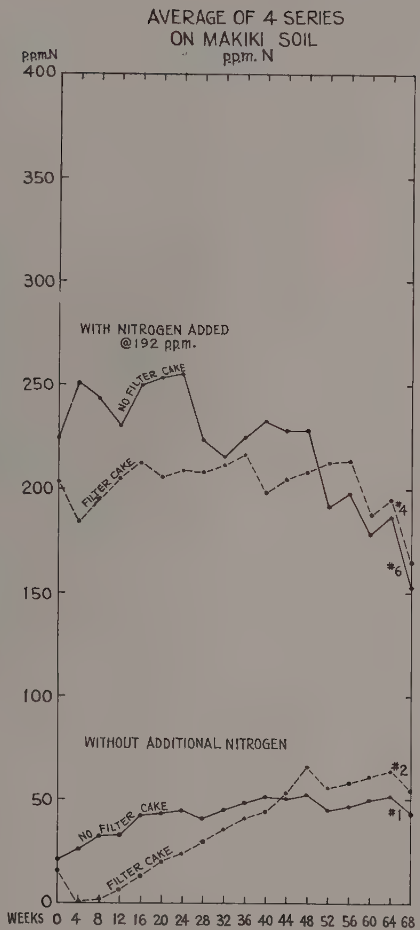


Fig. 13

The drop in the nitrogen content of Treatment No. 6 of this series on the Manoa soil in February 1939 may be in some way related to its higher moisture content. The soil sample when taken was saturated with water which unfortunately had come from a leak in the glass roof during a rain. The apparent permanency of this lower nitrogen content is hard to explain, however, since the excess water had all been caught in the drainage pan under the pot and was subsequently returned to the soil. Furthermore, the adjacent and comparable pot with Makiki soil which was also wet through the same cause did not show any loss of nitrogen. Thus for a period of only a few weeks this Manoa soil was somewhat wetter than usual.

Figs. 12 and 13: Averages of all 4 series. In these two figures we show the composite picture of the 4 treatments on both soils which we have shown as individual series in the foregoing graphs. Hence, disregarding seasonal effects, which under the conditions of our study are insignificant in comparison with the effects of the elapsed time intervals after the treatment applications, Figs. 12 and 13 tell a

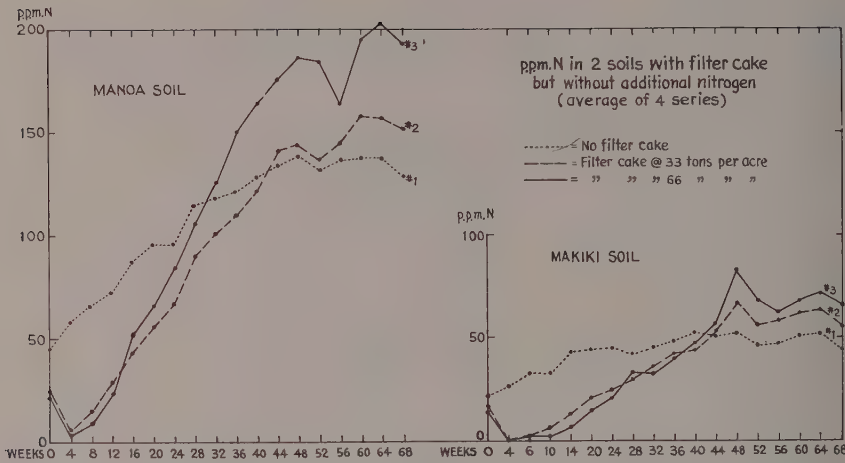


Fig. 14

story which has its practical significance. For instance, even when optimum conditions are provided for the maximum activity of soil microorganisms, the incorporation in a soil of an organic material like filter cake with its wide ratio of carbon-to-nitrogen will reduce the normal amount of available soil nitrogen for approximately a year thereafter. Hence the return of this nitrogen which has been tied up in this way by the microorganisms, together with the probable release of a very small part of the nitrogen originally carried by the organic matter itself, may come so late in the growth of a crop of sugar cane that it will probably have the same effect as a late application of nitrogen, *i.e.*, it will produce more cane with a poorer quality at harvest.

Periodic, unexplainable variations in the available nitrogen supply of different soils, following an initial application of nitrogen fertilizer, indicate that similar variations may be expected to occur each time that nitrogen fertilizer is applied to the growing crop. It is further surmised that the more slowly decomposable soil organic materials will likewise affect this variation when later nitrogen applications are made. Such conditions will undoubtedly have their corresponding influence upon the amount of nitrogen that would be available for absorption by a growing crop.

Fig. 14: To more clearly compare the differences between the two soils to which filter cake but no additional nitrogen fertilizer had been added, we present Fig. 14. The depression in the available soil nitrogen was of slightly shorter duration on the Manoa soil where the heavier amount of filter cake was concerned, but with the smaller (33-ton) application both soils were below the controls (Treatment No. 1) for 44 weeks.

At the end of 70 weeks the corresponding amounts of nitrogen finally contributed by the filter cake to the Manoa soil were more than double those to the Makiki soil. However, it is doubtful if this greater contribution to the Manoa soil amounts to more than about 25 per cent of the total nitrogen content of the filter cake which was originally applied.

Fig. 15: The data shown on this graph, No. 15, are from the soils which had not received any filter cake, but which had been supplied with different amounts of nitrogen fertilizer.

Without nitrogen fertilization the Makiki soil shows only minor fluctuations in its available soil nitrogen content during the entire period of 70 weeks. Such nitrogen content is less than half the total found in the corresponding treatment on the Manoa soil, which in the same period has increased its available nitrogen supply by about 100 p.p.m.

With nitrogen fertilizer applications equivalent to 300 pounds per acre, the picture is changed. The variations in both soils throughout the 70-week period are considerably greater and in the case of the Makiki soil there is a definite loss of available nitrogen. Thus the difference in nitrogen content between these two soils is shown to be increasingly greater with time.

This is more strikingly shown when the nitrogen fertilization was equivalent to 600 pounds per acre, and here the continued loss of available nitrogen from the Makiki soil needs a real explanation which we are unable to provide.

Fig. 16: A supplementary study, wherein both ammonium sulphate and nitrate of soda were compared with the ammonium nitrate we have used in the treatments previously discussed, shows the great similarity of effects from all three nitrogen carriers when used in addition to filter cake on both soils. Such differences in the amounts of available soil nitrogen as were measured between the different sources of nitrogen are probably not greater than would occur by chance alone.

Fig 17: The data shown in Fig. 17 indicate the rapidity with which ammonium sulphate was nitrified by these soils under the favorable conditions that were provided. On the Manoa soil the ammonia was completely nitrified within a period of ten weeks; on the Makiki soil under the same conditions, it required sixteen weeks to completely nitrify the ammoniacal nitrogen. Thus we have vivid evidence of beneficial microorganic activity in these soils.

Conclusion: It is quite apparent from the data presented herein that soil fertility includes something else besides N, P, and K. It is our feeling that this "something else" is largely the relationship between the soil organic matter and its rate of decomposition. This organic matter may have been produced "in place" or it may have come from outside sources. Its rate of decomposition will be governed largely by the number and kinds of microorganisms, and their abundance and activities will be under the influence of the soil's structure, aeration, moisture, temperature, reaction, and the mineral plant food that is present or supplied. Until we acquire more adequate knowledge of these microorganisms and skill in regulating the carbon/nitrogen relations in our continually cultivated cane soils, we are not in a position to handle nitrogen fertilization in a way that will result in its maximum economic efficiency.

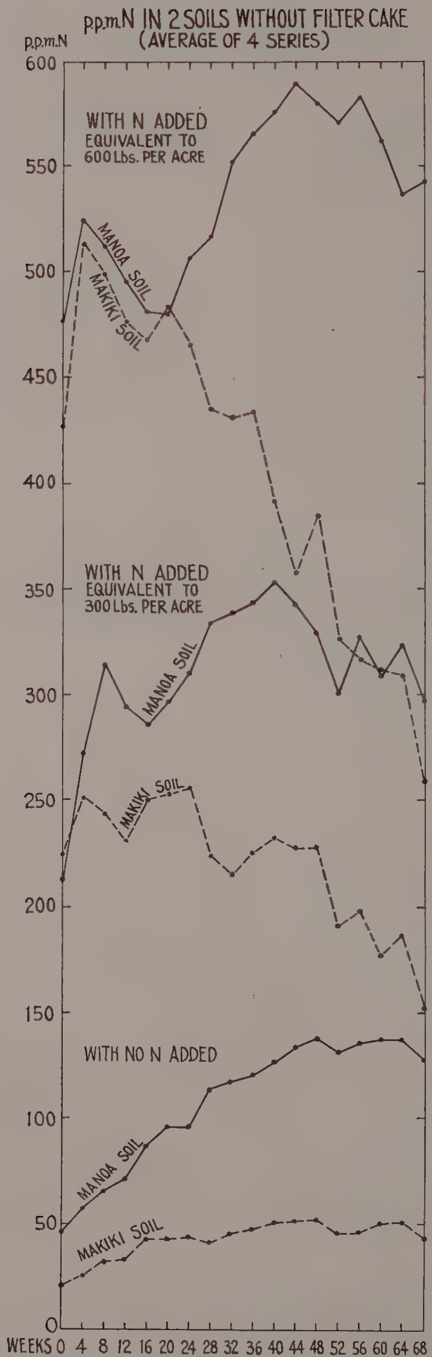

p.p.m.N IN 2 SOILS WITHOUT FILTER CAKE
(AVERAGE OF 4 SERIES)
p.p.m.N
WITH N ADDED
EQUIVALENT TO
600 Lbs. PER ACRE
MANOA SOIL
MAKIKI SOIL
WITH N ADDED
EQUIVALENT TO
300 Lbs. PER ACRE
MANOA SOIL
MAKIKI SOIL
WITH NO N ADDED
MANOA SOIL
MAKIKI SOIL
WEEKS

Fig. 15

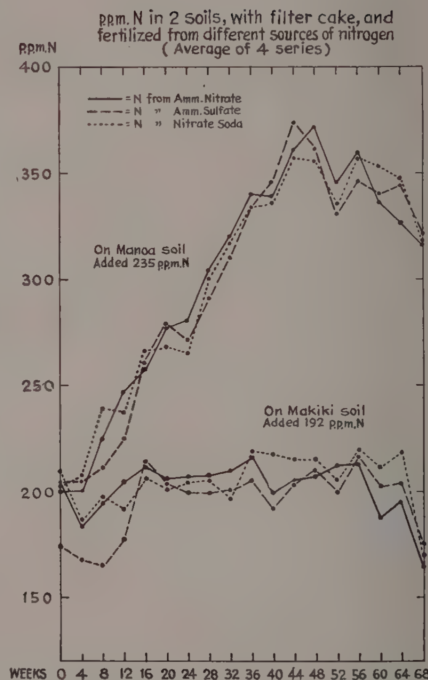

p.p.m. N in 2 soils, with filter cake, and fertilized from different sources of nitrogen
(Average of 4 series)
p.p.m.N
= N from Amm. Nitrate
= N " Amm. Sulfate
= N " Nitrate Soda
On Manoa soil
Added 235 p.p.m.N
On Makiki soil
Added 192 p.p.m.N
WEEKS

Fig. 16

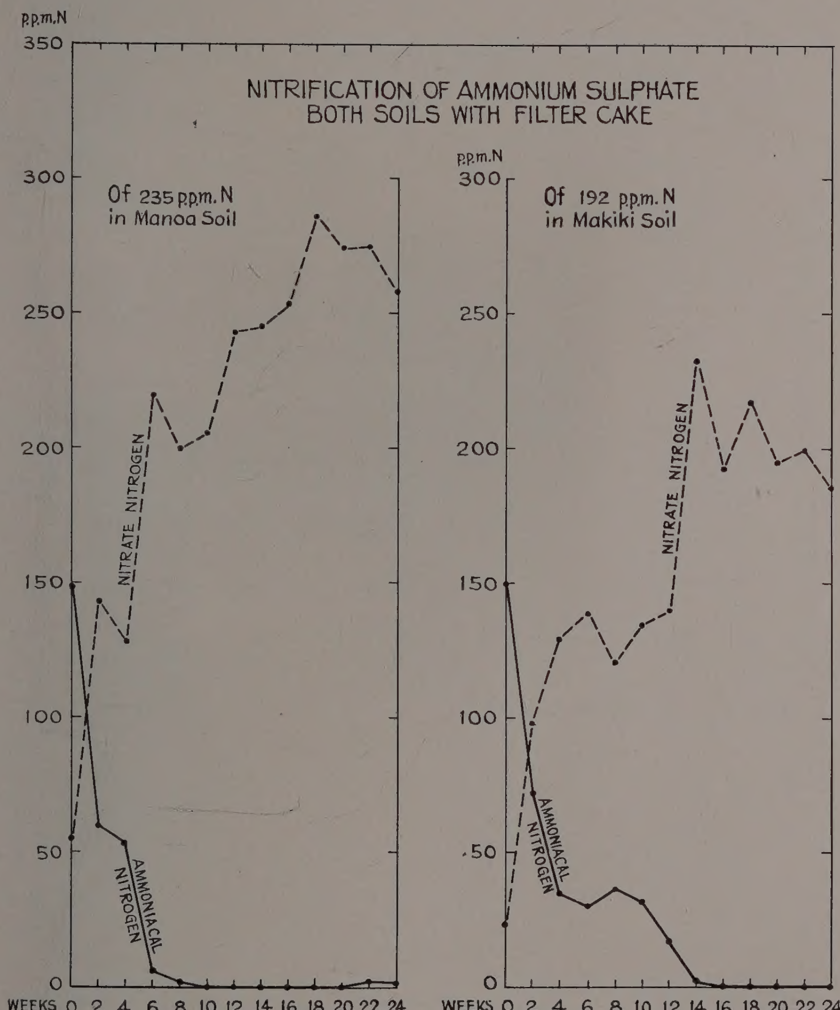

NITRIFICATION OF AMMONIUM SULPHATE
BOTH SOILS WITH FILTER CAKE
P.P.m.N
350
300
250
200
150
100
50
0
Of 235 p.p.m.N
in Manoa Soil
NITRATE NITROGEN
AMMONIACAL NITROGEN
WEEKS 0 2 4 6 8 10 12 14 16 18 20 22 24
P.P.m.N
300
250
200
150
100
50
0
Of 192 p.p.m.N
in Makiki Soil
NITRATE NITROGEN
AMMONIACAL NITROGEN
WEEKS 0 2 4 6 8 10 12 14 16 18 20 22 24

Fig. 17

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
SEPTEMBER 16, 1940, TO DECEMBER 14, 1940

Date	Per pound	Per ton	Remarks
Sept. 16, 1940...	2.67¢	$53.40	Puerto Ricos.
" 24........	2.73	54.60	Philippines.
" 25........	2.75	55.00	Philippines.
Oct. 8........	2.755	55.10	Philippines, 2.76, 2.75.
" 9........	2.78	55.60	Puerto Ricos.
" 14........	2.77	55.40	Philippines.
" 21........	2.80	56.00	Puerto Ricos, Philippines.
" 23........	2.83	56.60	Cubas.
" 24........	2.85	57.00	Philippines.
" 29........	2.87	57.40	Puerto Ricos, Philippines.
Nov. 6........	2.90	58.00	Puerto Ricos, Philippines.
" 13........	2.905	58.10	Philippines, 2.91; Puerto Ricos, 2.90.
" 14........	2.90	58.00	Philippines.
" 22........	2.85	57.00	Cubas.
Dec. 4........	2.865	57.30	Cubas, 2.85; Puerto Ricos, 2.88; Cubas, 2.88.
" 5........	2.87	57.40	Cubas.
" 10........	2.915	58.30	Philippines, 2.90, 2.93.
" 12........	2.95	59.00	Philippines.
" 14........	2.93	58.60	Puerto Ricos.

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